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Washington, D.C. 20591

Development of a Supplemental Inspection Document for the Fairchild SA226 and SA227 Aircraft, Part 2, Volume II

October 1999

Technical Report

U.S. Department of Transportation
Federal Aviation Administration

NOTICE

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16. Abstract

This report (consisting of volume I and volume II) is the second phase of a three-phase program sponsored by the Federal Aviation Administration to develop a supplemental inspection document for Fairchild SA226 and SA227 aircraft. In this report, the results of material characterization and testing are presented. Crack growth analysis of all the critical structural elements using NASGRO is performed and the results documented.

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GSFC    GODDARD PAYLOAD SPECTRUM
       2, -100.00,  100.00, -100.00,  100.00, -100.00,  100.00, -100.00, 100.
       4,  -90.00,   90.00,  -90.00,   90.00,  -90.00,   90.00,  -90.00,  90.
       8,  -80.00,   80.00,  -80.00,   80.00,  -80.00,   80.00,  -80.00,  80.
      15,  -70.00,   70.00,  -70.00,   70.00,  -70.00,   70.00,  -70.00,  70.
      49,  -60.00,   60.00,  -60.00,   60.00,  -60.00,   60.00,  -60.00,  60.
      81,  -50.00,   50.00,  -50.00,   50.00,  -50.00,   50.00,  -50.00,  50.
     178,  -40.00,   40.00,  -40.00,   40.00,  -40.00,   40.00,  -40.00,  40.
     641,  -30.00,   30.00,  -30.00,   30.00,  -30.00,   30.00,  -30.00,  30.
    3120,  -20.00,   20.00,  -20.00,   20.00,  -20.00,   20.00,  -20.00,  20.
    3405,  -10.00,   10.00,  -10.00,   10.00,  -10.00,   10.00,  -10.00,  10.
    5019,   -7.00,    7.00,   -7.00,    7.00,   -7.00,    7.00,   -7.00,   7.
   28853,   -5.00,    5.00,   -5.00,    5.00,   -5.00,    5.00,   -5.00,   5.
   91655,   -3.00,    3.00,   -3.00,    3.00,   -3.00,    3.00,   -3.00,   3.
0/
CONS1   CONSTANT AMPLITUDE LOADING
       1,    1.00,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,  -1.
0/
TAXI    Taxi Spectrum for Metro 226
  1.9000,    -.30,    0.30,   -0.30,    0.30,    -.30,    0.30,   -0.30,    0.30,
   .0900,    -.40,    0.40,   -0.40,    0.40,    -.40,    0.40,   -0.40,    0.40,
   .0100,    -.46,    0.46,   -0.46,    0.46,    -.46,    0.46,   -0.46,    0.46,
0/
GUST-L  Gust & Maneuver Spectrum (2 HR) For Long Range Flight Metro 226
   38.28571,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,
    4.57143,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,
    2.28572,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,
     .45714,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,
     .08286,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,
     .02057,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,
     .00686,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,
     .00240,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,
     .00074,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,
     .00086,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,
0/
GUST-M  Gust & Maneuver Spectrum (1 Hour) For Medium Range Flight Metro 226
   19.14286,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,
    2.28571,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,
    1.14286,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,
     .22857,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,
     .04143,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,
     .01029,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,
     .00343,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,
     .00120,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,
     .00037,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,
     .00043,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,
0/
GUST-S  Gust & Maneuver Spectrum (30 MIN) For Short Range Flight Metro 226
    9.57143,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,   -0.30,    0.30,
    1.14286,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,   -0.50,    0.50,
     .57143,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,   -0.60,    0.60,
     .11429,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,   -0.80,    0.80,
     .02071,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,   -1.00,    1.00,
     .00514,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,   -1.20,    1.20,
     .00171,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,   -1.40,    1.40,
     .00060,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,   -1.60,    1.60,
     .00019,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,   -1.80,    1.80,
     .00021,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,   -2.00,    2.00,
0/
GUST-L7  Gust & Maneuver Spectrum (2 HR) For Long Range Flight SA227
   00.00000,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,
   24.51503,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,
    2.72800,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,
     .46463,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,
     .10640,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,
     .02640,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,
```

```
     .00960,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,
     .00297,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,
     .00114,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,
     .00051,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,
0/
GUST-M7  Gust & Maneuver Spectrum (1 HR) For Medium Range Flight SA227
   00.00000,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,
   31.10351,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,
    2.98177,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,
     .44934,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,
     .09423,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,
     .02326,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,
     .00757,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,
     .00231,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,
     .00080,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,
     .00034,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,
0/
GUST-S7  Gust & Maneuver Spectrum (0.5 HR) For Short Range Flight SA227
   00.00000,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,   -0.00,    0.00,
   15.09007,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,   -0.22,    0.22,
    1.52174,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,   -0.43,    0.43,
     .23221,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,   -0.65,    0.65,
     .04871,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,   -0.87,    0.87,
     .01210,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,   -1.08,    1.08,
     .00397,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,   -1.30,    1.30,
     .00123,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,   -1.52,    1.52,
     .00043,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,   -1.73,    1.73,
     .00017,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,   -1.95,    1.95,
0/
LAND-21  Landing Spectrum - Metro 226 gage 21
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,
   .4400,    0.81,    1.12,    0.81,    1.12,    0.81,    1.12,    0.81,    1.12,
   .2200,    0.61,    1.23,    0.61,    1.23,    0.61,    1.23,    0.61,    1.23,
   .0590,    0.42,    1.33,    0.42,    1.33,    0.42,    1.33,    0.42,    1.33,
   .0048,    0.22,    2.44,    0.22,    2.44,    0.22,    2.44,    0.22,    2.44,
   .0012,    0.03,    2.55,    0.03,    2.55,    0.03,    2.55,    0.03,    2.55,
0/
LAND-26 Landing Spectrum - Metro 226 gage 26
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,
   .4400,    0.00,    1.74,    0.00,    1.74,    0.00,    1.74,    0.00,    1.74,
   .2200,   -1.00,    2.48,   -1.00,    2.48,   -1.00,    2.48,   -1.00,    2.48,
   .0590,   -2.00,    3.22,   -2.00,    3.22,   -2.00,    3.22,   -2.00,    3.22,
   .0048,   -3.00,    3.96,   -3.00,    3.96,   -3.00,    3.96,   -3.00,    3.96,
   .0012,   -4.00,    4.70,   -4.00,    4.70,   -4.00,    4.70,   -4.00,    4.70,
0/
LAND-25 Landing Spectrum - gage 25
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,
   .4400,    0.80,    1.10,    0.80,    1.10,    0.80,    1.10,    0.80,    1.10,
   .2200,    0.60,    1.20,    0.60,    1.20,    0.60,    1.20,    0.60,    1.20,
   .0590,    0.40,    1.30,    0.40,    1.30,    0.40,    1.30,    0.40,    1.30,
   .0048,    0.20,    1.40,    0.20,    1.40,    0.20,    1.40,    0.20,    1.40,
   .0012,    0.00,    1.50,    0.00,    1.50,    0.00,    1.50,    0.00,    1.50,
0/
LAND-23  Landing Spectrum  - Metro 226 Gage 23
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.00,    1.00,    1.00,
   .4400,    0.81,    1.06,    0.81,    1.06,    0.81,    1.06,    0.81,    1.06,
   .2200,    0.62,    1.12,    0.62,    1.12,    0.62,    1.12,    0.62,    1.12,
   .0590,    0.43,    1.18,    0.42,    1.18,    0.43,    1.18,    0.43,    1.18,
   .0048,    0.23,    1.24,    0.23,    1.24,    0.23,    1.24,    0.23,    1.24,
   .0012,    0.04,    1.30,    0.04,    1.30,    0.04,    1.30,    0.04,    1.30,
0/
LAND-G   Estimated peak G's based on drop test
   .2750,   -0.55,    0.55,   -0.55,    0.55,   -0.55,    0.55,   -0.55,    0.55,
   .4400,   -0.57,    0.57,   -0.57,    0.57,   -0.57,    0.57,   -0.57,    0.57,
   .2200,   -0.62,    0.62,   -0.62,    0.62,   -0.62,    0.62,   -0.62,    0.62,
   .0590,   -0.70,    0.70,   -0.70,    0.70,   -0.70,    0.70,   -0.70,    0.70,
   .0048,   -0.82,    0.82,   -0.82,    0.82,   -0.82,    0.82,   -0.82,    0.82,
   .0012,   -0.98,    0.98,   -0.98,    0.98,   -0.98,    0.98,   -0.98,    0.98,
```

```
0/
LAND-22  Landing Spectrum - Metro 226 gage 21
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,
   .4400,    0.75,    1.23,    0.75,    1.23,    0.75,    1.23,    0.75,    1.23,
   .2200,    0.50,    1.46,    0.50,    1.46,    0.50,    1.46,    0.50,    1.46,
   .0590,    0.26,    1.69,    0.26,    1.69,    0.26,    1.69,    0.26,    1.69,
   .0048,    0.01,    1.92,    0.01,    1.92,    0.01,    1.92,    0.01,    1.92,
   .0012,   -0.24,    2.14,   -0.24,    2.14,   -0.24,    2.14,   -0.24,    2.14,
0/
LAND-24  Landing Spectrum - Metro 226 gage 24
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,
   .4400,    0.79,    1.07,    0.79,    1.07,    0.79,    1.07,    0.79,    1.07,
   .2200,    0.59,    1.14,    0.59,    1.14,    0.59,    1.14,    0.59,    1.14,
   .0590,    0.38,    1.21,    0.38,    1.21,    0.38,    1.21,    0.38,    1.21,
   .0048,    0.17,    1.29,    0.17,    1.29,    0.17,    1.29,    0.17,    1.29,
   .0012,   -0.04,    1.36,   -0.04,    1.36,   -0.04,    1.36,   -0.04,    1.36,
0/
LAND-28  Landing Spectrum - Metro 226 gage 28
   .2750,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,    1.00,    1.01,

   .4400,   -1.84,    4.64,   -1.84,    4.64,   -1.84,    4.64,   -1.84,    4.64,
   .2200,   -4.69,    8.28,   -4.69,    8.28,   -4.69,    8.28,   -4.69,    8.28,
   .0590,   -7.53,   11.92,   -7.53,   11.92,   -7.53,   11.92,   -7.53,   11.92,
   .0048,  -10.37,   15.56,  -10.37,   15.56,  -10.37,   15.56,  -10.37,   15.56,
   .0012,  -13.22,   19.20,  -13.22,   19.20,  -13.22,   19.20,  -13.22,   19.20,
0/
PRESS-7  Pressure Cycle 7 psi
       1,    0.00,    1.00,    0.00,    1.00,    0.00,    1.00,    0.00,    1.00,
0/
GND      Ground fuselage reading
       1,    0.00,    0.01,    0.00,    0.01,    0.00,    0.01,    0.00,    0.00,
0/
PROP-14    Gage 14
     624,    -0.3,    1.00,    -0.3,    1.00,    -0.3,    1.00,    -0.3,    1.00,
0/
PROP-15    Gage 15
     624,    -2.2,    1.00,    -2.2,    1.00,    -2.2,    1.00,    -2.2,    1.00,
0/
THRUST
       1,     0.0,    1.00,     0.0,    1.00,     0.0,    1.00,     0.0,    1.00,
0/
```

APPENDIX E FORTRAN SOURCE CODE FOR MODIFIED CRACK CASES

```
SUBROUTINE SITC11(SAFE,MODE,SMIN4,SMAX4,C,NSQUAN,IHDSQ,MSOP,
     K         SR,DELTAK,CAYMAX,F0,F3,FDUM1,FDUM2,NJOB,
     K                    NETMSG,SFLO1,SYLD1,IACMSG,ISESS,*,*)
CD0
CD0   IDENTIFICATION
CD0
CD0         SUBROUTINE SITCA3(MODE,SMIN4,SMAX4,C,NSQUAN,IHDSQ,MSOP,
CD0        K         SR,DELTAK,CAYMAX,F0,F3,FDUM1,FDUM2,NJOB,
CD0        K                    NETMSG,SFLO1,SYLD1,IACMSG,*)
CD0
CD0         PROGRAMMER -
CD0          MODIFIED FOR BATCH - L.C. WILLIAMS 4/93
C97          MODIFIED -- ADDITIONAL MATERIAL CONSIDERATION.. CHEN 7/97
C98          MODIFIED -- CORRECTED ERRORS IN 7/97 MOD.. J VANCE 9/98
CD1
CD1   PURPOSE
CD1
CD1         CONTROL OF INPUT, OUTPUT, CALCULATION, AND PROOF-TEST
CD1         FOR THROUGH CRACK FROM HOLE IN PLATE.
CD2
CD2   CALLING ARGUMENT INPUT
CD2
CD2         C      - CRACK LENGTH, C
CD2         MODE   - 'IPUT','OPUT','CALC', OR 'PRUF'
CD2         NETMSG - FLAG TO CHECK NET STRESS > YIELD STRESS (0=CHECK)
CD2         NJOB   - NO. OF TIMES THROUGH ROUTINE
CD2         SMAX4  - (t1) STRESSES CORR. TO F0,F3,FDUM1,FDUM2
CD2         SMIN4  - (t2) STRESSES CORR. TO F0,F3,FDUM1,FDUM2
CD2         SYLD1  - YIELD STRESS
CD3
CD3   CALLING ARGUMENT OUTPUT
CD3
CD3         *      - RETURN1
CD3         CAYMAX - SIF<MAX>
CD3         DELTAK - SIF<MAX> - SIF<MIN>
CD3         F0     - NONDIMENSIONALIZED SIF FOR 1ST STRESS QUANTITY, S0
CD3         F3     - NONDIMENSIONALIZED SIF FOR 2ND STRESS QUANTITY, S3
CD3         FDUM1   - NONDIMENSIONALIZED SIF FOR UNUSED STRESS QUANTITY
CD3         FDUM2   - NONDIMENSIONALIZED SIF FOR UNUSED STRESS QUANTITY
CD3         IHDSQ  - (15,4) ARRAY OF 4 60-CHAR STRESS DESCRIPTIONS
CD3         NETMSG - FLAG TELLING IF NET STRESS > YIELD STRESS (1=TRUE)
CD3         NSQUAN - NO. OF STRESS QUANTITIES
CD3         SR     - 1 - DELTAK/CAYMAX
CD5
CD5   INTERNAL VARIABLES
CD5
CD5         ALPHA     - D/(D+2C)
CD5         AMBDA     - (PI/2) * (D+C) / (2B - C)
CD5         BOUND     - B - (D/2)
CD5         CONST     - SQRT(PI*C)
CD5         EPSI      - CORRECTION FOR CRACK TIP PLASTIC ZONE
CD5         PI        - 3.14159...
CD5         RNET1...3 - MEAN NET SECTION STRESS
CD5      OTHER VALUES DEFINED IN EQUATIONS
CD9
CD9   SPECIAL COMMENTS
CD9
CD9         SUBROUTINES CALLED: INTC03, OPTC03
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*80 MSOP(6)
      CHARACTER*1 SAFE,AREF,WFCHEK
      CHARACTER*4 MODE,IHDSQ(15,4)
      DIMENSION SMIN4(4),SMAX4(4)
```

```
      COMMON /GEO/ T,D,W,B,SBB,XFIL(15)
      COMMON/NETOUT/SNETVT,SNETRT,SNETV(4),SNETR(4)
      COMMON /IOUNTS/ IIN,IOU,IBF
C ADDED 7/21/97
      COMMON /TC11/ AREATC11, AITC11, CENTTC11
      COMMON /JUDGE/ AIJC


      DATA PI/3.14159265358979D0/
      DATA EPSI/0.13D0/




C       OPEN (UNIT=74,FILE='1111SDEL.TXT',STATUS='UNKNOWN')
C
C*******************************************************************
C
C                                                  Calc or 'Proof Test' Mode
C
      IF (MODE.EQ.'CALC'.OR.MODE.EQ.'PRUF') THEN
C
C                                                           Geometric checks
C
          BOUND = B - 0.5D0*D
          IF (C.LT.0D0.OR.C.GE.BOUND) THEN
              IF (MODE.EQ.'CALC') WRITE (7,60001) C,BOUND
              IF (MODE.EQ.'CALC') WRITE (IOU,60001) C,BOUND
              IF (MODE.EQ.'PRUF') WRITE (7,60002) C,BOUND
              IF (MODE.EQ.'PRUF') WRITE (IOU,60002) C,BOUND
              RETURN 1
          ENDIF

C=X=X=X=X=X=X=X=X=X=X
C   AREA3 IS ADDITIONAL AREA NOT PART OF THE PLATE WITH THE OFF-CENTER HOLE

              AREA3 = AREATC11

C=X=X=X=X=X=X=X=X=X=X
C       SDEL = RECIPROCAL OF REDUCTION FACTOR FOR REMOTE STRESS.  SDEL
C               IS GREATER THAN 1
C

               SDEL = (W/(W-C))*((W-C)*T + AREA3)/(W*T + AREA3)


C
C                                        Check if Net stress > Yield stress
C
              PF0    = DMAX1(DABS(SMAX4(1)/SDEL),DABS(SMIN4(1)/SDEL))*W*T
              PF3    = DMAX1(DABS(SMAX4(2)/SDEL),DABS(SMIN4(2)/SDEL))*D*T
              AL1    = W - B - D/2D0
              AL2    = B - C - D/2D0
              AREA1 = AL1*T
              AREA2 = AL2*T
              AREA   = AREA1 + AREA2 + AREA3
C=X=X=X=X=X=X=X=X=X=X
C       S0A & S3A ARE P/A STRESSES
C

              S0A    = PF0/(AREA1 + AREA2)
              S3A    = PF3/(AREA1 + AREA2)
              EX1    = AL1/2D0
              EX2    = W - AL2/2D0
C=X=X=X=X=X=X=X=X=X=X
C       CENTTC11 IS CENTROID OF ADDITIONAL AREA WRT PART EDGE
C       EXC IS CENTROID OF W*T AND AREA3
C
               EX3    = CENTTC11
              EXB    = (AREA1*EX1 + AREA2*EX2 + AREA3*EX3)/AREA
              EXC    = (W*T*W/2D0 + AREA3*EX3)/(W*T + AREA3)
```

```
              QOFF  = DABS(EXC - EXB)
              AI1   = T*AL1**3/12D0 + AREA1*(EX1-EXB)**2
              AI2   = T*AL2**3/12D0 + AREA2*(EX2-EXB)**2
C=X=X=X=X=X=X=X=X=X=X=X
C       AITC11 IS MOMENT OF INERTIA OF ADDITIONAL AREA ABOUT CENTROID
C       OF THE CROSS SECTION
C
              AI3   = AITC11
              AI    = AI1 + AI2 + AI3
C=X=X=X=X=X=X=X=X=X=X=X
C       S0B, S3B IS MC/I FOR TWO PORTIONS OF CRACKED PLATE
C
              EXD   = (AREA1*EX1 + AREA2*EX2)/(AREA1+AREA2)
              S0B   = PF0*QOFF*((1D0-EPSI)*W - EXB)/AI
              S3B   = PF3*(W-B-EXD)*((1D0-EPSI)*W - EXB)/AI
C=X=X=X=X=X=X=X=X=X=X=X
C       TOTAL STRESS ON CRACKED PLATE MC/I + P/A

              SNETVT = S0A+S0B+S3A+S3B
              SNETRT = SNETVT/SYLD1

C ... CHECK FOR YIELD ONE TIME OR FLOW ALWAYS
          IF (NETMSG.EQ.0.AND.SNETVT.GE.SYLD1) THEN
              NETMSG=1

                  WRITE(*,*)' THE SNETVT   ',SNETVT

          END IF
C
            IF (SNETVT.GE.SFLO1) THEN
              NETMSG=5
            ENDIF
C
C                                                                  Compute SIFs
C

          ALPHA  = D/(D+2D0*C)
          AMBDA  = (PI/2D0)*(D+C)/(2D0*B-C)
          G0     = 0.7071D0+ALPHA*(0.7548D0+ALPHA*(0.3415D0+
     K                        ALPHA*(0.642D0+ALPHA*0.9196D0)))
          G1     = ALPHA*(0.078D0+ALPHA*(0.7588D0+ALPHA*((-0.4293D0)+
     K                                ALPHA*(0.0644D0+ALPHA*0.651D0))))
          GW     = DSQRT(SBB/DCOS(AMBDA))
          F0     = G0*GW
          F3     = (0.5D0*G0*D/W + G1)*GW
          FDUM1 = 0.0D0
          FDUM2 = 0.0D0
          CONST  = DSQRT(PI*C)
          IF (MODE.EQ.'CALC') THEN


C            CAYMAX = CONST*DMAX1( (SMAX4(1)*F0+DABS(SMAX4(2))*F3),
C     K           +                (SMIN4(1)*F0+DABS(SMIN4(2))*F3) )

C=X=X=X=X=X=X=X=X=X=X=X
C       SDEL REDUCES SMAX AND SMIN TO ACCOUNT FOR LOAD TRANSFER
C       TO ADDITIONAL AREA

           CAYMAX=CONST*DMAX1((SMAX4(1)/SDEL*F0+DABS(SMAX4(2)/SDEL)*F3),
     K           +            (SMIN4(1)/SDEL *F0+DABS(SMIN4(2)/SDEL)*F3) )

C            DELTAK=CONST*F0*DABS( SMAX4(1) - SMIN4(1) )

            DELTAK=CONST*F0*DABS( SMAX4(1)/ SDEL - SMIN4(1)/ SDEL)


C          CALCULATE DELTAK DUE TO PIN LOAD ALONE
C             DELTK2 = DABS( SMAX4(2)-SMIN4(2) )*F3*CONST

            DELTK2 = DABS( SMAX4(2)/ SDEL-SMIN4(2)/ SDEL )*F3*CONST
```

```
C... ADD THE DELTAK VALUES
            DELTAK = DELTAK+DELTK2

          ELSE IF (MODE.EQ.'PRUF') THEN
C            CAYMAX = CONST*(SMAX4(1)*F0+DABS(SMAX4(2))*F3)
            CAYMAX = ( CONST*(SMAX4(1)/SDEL*F0+DABS(SMAX4(2)/SDEL)*F3) )
          ENDIF


          IF (CAYMAX.NE.0D0) THEN
                SR = 1D0 - DELTAK/CAYMAX
C                 WRITE(74,*)' DELTAK/CAYMAX =',DELTAK/CAYMAX

          ENDIF
C
C                                                          Input Mode
C
      ELSE IF (MODE(1:1).EQ.'I') THEN
          CALL INTC11(NJOB,NSQUAN,MODE,IHDSQ,ISESS,*100)
C
C                                                         Output Mode
C
      ELSE IF (MODE.EQ.'OPUT') THEN
          CALL OPTC11(MSOP)
C
C                                                 Extraordinary ending
C
      ELSE
          WRITE (7,60009) MODE
          WRITE (IOU,60009) MODE
          RETURN 1
      ENDIF


C      WRITE(*,*)' RUNNING THROUGH CRACK .. TC 11'


      RETURN
C
C - Return to previous prompt.
 100  RETURN 2
C-----------------------------------------------------------
C
60001 FORMAT(/' ',10X,'FINAL RESULTS:'/
     K            11X,'Crack outside geometric bounds:'/
     K            11X,'c = ',G12.4,'  B - (D/2) = ',G12.4)
60002 FORMAT(/' ',10X,'Crack outside bounds: c = ',
     K            G12.4,'  B - (D/2) = ',G12.4)
60009 FORMAT(/' ',10X,
     K             'Program coding error in Sbrtn SITC03: MODE = ',A4)
      END


SUBROUTINE SITC12(SAFE,MODE,SMIN4,SMAX4,C,NSQUAN,IHDSQ,MSOP,
     K         SR,DELTAK,CAYMAX,F0,F1,F2,FDUM1,NJOB,
     K                    NETMSG,SFLO1,SYLD1,IACMSG,ISESS,*,*)

C97
C97         8/97 MODIFIED BY JUDGE CHEN ... ADDITIONAL AREA ADDED
C97         THIS SUBROUTINE IS SIMILAR TO SITC02
C97
C98         10/98 MODIFIED BY J VANCE... REV EQUATION FOR AND USE
C98         OF 'SDEL'
CD0
CD0    IDENTIFICATION
CD0
CD0         SUBROUTINE SITC02(MODE,SMIN4,SMAX4,C,NSQUAN,IHDSQ,MSOP,
CD0        K         SR,DELTAK,CAYMAX,F0,F1,F2,FDUM1,NJOB,
CD0        K                    NETMSG,SFLO1,SYLD1,IACMSG,*)
```

```
CD0
CD0        PROGRAMMER - S. PIOTROWSKI, LOCKHEED-EMSCO
CD0         MODIFIED FOR BATCH - L.C. WILLIAMS 4/93
CD1
CD1   PURPOSE
CD1
CD1        CONTROL OF INPUT, OUTPUT, CALCULATION AND PROOF-TEST
CD1        FOR SINGLE EDGE THROUGH CRACK.
CD2
CD2   CALLING ARGUMENT INPUT
CD2
CD2        C      - CRACK LENGTH, C
CD2        MODE   - 'IPUT','OPUT','CALC', OR 'PRUF'
CD2        NETMSG - FLAG TO CHECK NET STRESS > YIELD STRESS (0=CHECK)
CD2        NJOB   - NO. OF TIMES THROUGH ROUTINE
CD2        SMAX4  - (t1) STRESSES CORR. TO F0,F1,F2,FDUM1
CD2        SMIN4  - (t2) STRESSES CORR. TO F0,F1,F2,FDUM1
CD2        SYLD1  - YIELD STRESS
CD3
CD3   CALLING ARGUMENT OUTPUT
CD3
CD3        *      - RETURN1
CD3        CAYMAX - SIF<MAX>
CD3        DELTAK - SIF<MAX> - SIF<MIN>
CD3        F0     - NONDIMENSIONALIZED SIF FOR 1ST STRESS QUANTITY
CD3        F1     - NONDIMENSIONALIZED SIF FOR 2ND STRESS QUANTITY
CD3        F2     - NONDIMENSIONALIZED SIF FOR 3RD STRESS QUANTITY
CD3        IHDSQ  - (15,4) ARRAY OF 4 60-CHAR STRESS DESCRIPTIONS
CD3        NETMSG - FLAG TELLING IF NET STRESS > YIELD STRESS (1=TRUE)
CD3        NSQUAN - NO. OF STRESS QUANTITIES
CD3        SR     - 1 - DELTAK/CAYMAX
CD5
CD5   INTERNAL VARIABLES
CD5
CD5        BETA   - (PI*C)/(WD*2)
CD5        CONST  - SQRT(PI*C)
CD5        EPSI   - CORRECTION FOR CRACK TIP PLASTIC ZONE
CD5        FSINB  - 1 - SIN(BETA)
CD5        PI     - 3.14159...
CD5        RNET   - MEAN NET SECTION STRESS
CD5        Y      - SEC(BETA)*SQRT( TAN(BETA)/BETA )
CD9
CD9   SPECIAL COMMENTS
CD9
CD9        SUBROUTINES CALLED: INTC02, OPTC02
C
      IMPLICIT DOUBLE PRECISION (A-H,O-Z)
      CHARACTER*80 MSOP(6)
      CHARACTER*1 SAFE,AREF,WFCHEK
      CHARACTER*4 MODE,IHDSQ(15,4)
      DIMENSION SMIN4(4),SMAX4(4)
      COMMON /GEO/ TH,WD,XFIL(18)
      COMMON/NETOUT/SNETVT,SNETRT,SNETV(4),SNETR(4)
      COMMON /IOUNTS/ IIN,IOU,IBF
      COMMON /TC12JC/ AREA3,F3,G3,RIX,RIY,RM,IBARCNT
      COMMON /JUDGE/ AIJC
        DATA PI/3.14159265358979D0/
      DATA EPSI/0.13D0/

C
C*******************************************************************

C
C                                             CALC OR 'PROOF TEST' MODE
C
      IF(MODE.EQ.'CALC'.OR.MODE.EQ.'PRUF') THEN
C
C                                                        GEOMETRY CHECK
C
          IF (C.LT.0D0.OR.C.GE.WD) THEN
              IF (MODE.EQ.'CALC') WRITE (IOU,20000) C,WD
```

```
            IF (MODE.EQ.'CALC') WRITE(7,20000) C,WD
            IF (MODE.EQ.'PRUF') WRITE (IOU,20001) C,WD
            IF (MODE.EQ.'PRUF') WRITE(7,20001) C,WD
            RETURN 1
          ENDIF
C
C                                      CHECK NET STRESS > YIELD STRESS
C
C
C          SDEL IS RECIPROCAL OF STRESS REDUCTION FACTOR FOR LOAD
C          TRANSFER TO ADDITIONAL AREA (AREA3)
C
             SDEL = (WD/(WD-C))*((WD-C)*TH + AREA3)/(WD*TH + AREA3)
C          SDEL = 1.

C97            EPS2 = 1D0 - 2D0*EPSI
C97            TERM = WD / (WD - C)
C97           TERM2 = TERM * TERM
C97
C97            RNET = DMAX1( DABS(SMAX4(1)), DABS(SMIN4(1)) ) *
C97     K                     (TERM + EPS2*3D0*C*TERM2/WD)+
C97     K                DMAX1( DABS(SMAX4(2)),DABS(SMIN4(2)) )*TERM
C97            RNET = RNET + DMAX1(DABS(SMAX4(3)),DABS(SMIN4(3)))*EPS2*
C97     K                                                        TERM2
C97
C97            RNET = DMAX1( DABS(SMAX4(1)/SDEL), DABS(SMIN4(1)/SDEL) ) *
C97     K                       (TERM + EPS2*3D0*C*TERM2/WD)+
C97     K                DMAX1(DABS(SMAX4(2)/SDEL),DABS(SMIN4(2)/SDEL))*TERM
C97            RNET = RNET + DMAX1(DABS(SMAX4(3)/SDEL),
C97     K                                DABS(SMIN4(3)/SDEL))*EPS2*TERM2


C      WRITE(*,998)'AREA3','F3','G3','RIX','RIY','RM','IBARCNT'
C       WRITE(7,998)'AREA3','F3','G3','RIX','RIY','RM','IBARCNT'
C      WRITE(*,999)AREA3,F3,G3,RIX,RIY,RM,IBARCNT
C       WRITE(7,999)AREA3,F3,G3,RIX,RIY,RM,IBARCNT

      SUMA     = AREA3 + TH * (WD-C)
       SUMAX    = AREA3 * G3 + TH/2*(WD-C)**2
       SUMAXSQ = AREA3 * G3**2 + TH/4*(WD-C)**3
      SUMAY    = AREA3 * F3 + TH**2/2*(WD-C)
      SUMAYSQ = AREA3 * F3**2 + TH**3/4*(WD-C)

      SUMIOX   = RIX + (WD-C) * TH**3/12
      SUMIOY   = RIY + TH/12 * (WD-C)**3

      YBAR     = SUMAY/SUMA
      RIXCG    = SUMIOX + SUMAYSQ - YBAR*SUMAY

       XBAR     = SUMAX /SUMA
      RIYCG    = SUMIOY + SUMAXSQ - XBAR*SUMAX

C      IBACNT WAS SET IN INTC12.FOR
C      WAS ESTABLISHED FOR REFERENCE COUNT

      IF (IBARCNT .LE. 1) THEN
         XBAR1 = XBAR
         YBAR1 = YBAR
      ENDIF
       IBARCNT=IBARCNT+1


      EY       = YBAR - YBAR1
      EX       = XBAR - XBAR1


C Before the crack gets much beyond the initial length that was set,
c Take the first ybar calculated and then set it into another location
c called ybar1 and keep it there for later use
```

```
c Now find the bending stress about the entire section center of gravity
c about the strong axis but in the end of the crack.  Set the first xbar
c into xbar1, the same was as the ybar, to save it for use now.
c (Jack Simmons)

C Note that given the initial S2 value which is on the full uncracked face
c in order to find what that moment does to the net section, the moment
c from S@ is needed, then apply that moment to the net section thus
c M2 = S2 * T *W**2/6

ccc sample format   DMAX1( DABS(SMAX4(1)/SDEL), DABS(SMIN4(1)/SDEL) )
      S1 = RM * (YBAR - TH/2) / RIXCG
      S2MOD=S1+
     k        DMAX1( DABS(SMAX4(1)/SDEL), DABS(SMIN4(1)/SDEL) )*
     k        TH*WD*EY*YBAR/RIXCG
        S2PRIME=((YBAR-T)/YBAR) * S2MOD
        S2AVE = (S2PRIME + S2MOD) /2.
        SOPRIME = DMAX1( DABS(SMAX4(1)/SDEL), DABS(SMIN4(1)/SDEL)) +S2AVE
        SBX = S2MOD -S2SAVE
      S2P = (   (DMAX1( DABS(SMAX4(3)/SDEL), DABS(SMIN4(3)/SDEL) )*
     k        TH*WD**2)/6 +
     k        DMAX1( DABS(SMAX4(1)/SDEL), DABS(SMIN4(1)/SDEL) )*TH*WD*EX)
     k                                                *((WD-C)-XBAR)/RIYCG

        SNETVT=SOPRIME+SBX+S2P

C      WRITE(7,*)'        th','        wd','         c'
C        WRITE(7,999)Th,Wd,C
C       WRITE(7,*)'     XBAR1','     YBAR1'
C        WRITE(7,999)XBAR1,YBAR1
C        WRITE(7,*)'  SOPRIME','         SBX','        S2P'
C        WRITE(7,997)SOPRIME,SBX,S2P
C       WRITE(7,*)'SNETVT = ',SNETVT
      SNETRT=SNETVT/SYLD1
C       WRITE(7,*)'SNETVT = ',SNETVT
C       WRITE(7,*)' SYLD1 = ',SYLD1

C97            SNETVT = RNET
C97            SNETRT = SNETVT/SYLD1

C ... CHECK FOR YIELD ONE TIME OR FLOW ALWAYS
          IF (NETMSG.EQ.0.AND.SNETVT.GE.SYLD1) THEN
              NETMSG=1
          END IF
C
          IF (SNETVT.GE.SFLO1) THEN
              NETMSG=5
          ENDIF
C
C                                   CALCULATION OF STRESS INTENSITY FACTORS
C


               BETA    = 0.5D0*PI*C/WD
          IF (BETA.LT.1D-12) THEN
              Y   = 1D0
          ELSE
              Y   = DSQRT(DTAN(BETA)/BETA) / DCOS(BETA)
          ENDIF

          FSINB   = 1.D0 - DSIN(BETA)
          F0      = Y * (0.752 + 2.02*(C/WD) + 0.37*FSINB**3)
          F1      = F0/2.
          F2      = Y * (0.923 + 0.199*FSINB**4)
          FDUM1 = 0.0D0
          CONST   = DSQRT(PI*C)
          IF (MODE.EQ.'CALC') THEN

           CAYMAX = CONST*DMAX1( (F0*SMAX4(1)/SDEL
     K                    +F1*DABS(SMAX4(2))/SDEL +F2*SMAX4(3)/SDEL),
     K                      (F0*SMIN4(1)/SDEL + F1*DABS(SMIN4(2)/SDEL)
```

```
     K                                             +F2*SMIN4(3)/SDEL))
           DELTAK = CONST*( DABS( (F0*SMAX4(1)/SDEL + F2*SMAX4(3)/SDEL)-
     K                            (F0*SMIN4(1)/SDEL + F2*SMIN4(3)/SDEL))
     K                  + F1*DABS( SMAX4(2)/SDEL - SMIN4(2)/SDEL ) )
C      WRITE(7,996)'SMAX,SMIN, CONST,F0, DELTAK',SMAX4(1),SMIN4(1),CONST,
C     K                                 F0,DELTAK

          ELSE IF(MODE.EQ.'PRUF')THEN
           CAYMAX = CONST*( F0*SMAX4(1)/SDEL+F1*DABS(SMAX4(2)/SDEL)
     K                                      +F2*SMAX4(3)/SDEL )

         END IF


C ...... print values for checking
C          WRITE(IOU,*)'SMAX4....',SMAX4
C          WRITE(IOU,*)'SMIN4....',SMIN4
C          IF (MODE.EQ.'CALC') THEN
C              IF (DELTAK.LT.0D0) THEN
C                  CAYMAX = CAYMAX - DELTAK
C                  DELTAK = - DELTAK
C              ENDIF
C          ENDIF
          IF (CAYMAX.NE.0D0) SR = 1D0 - DELTAK/CAYMAX
C
C                                                           INPUT MODE
C
      ELSE IF (MODE(1:1).EQ.'I') THEN
          CALL INTC12(NJOB,NSQUAN,MODE,IHDSQ,ISESS,*100)
C
C                                                          OUTPUT MODE
C
      ELSE IF (MODE.EQ.'OPUT') THEN
          CALL OPTC12(MSOP)
       WRITE(*,*)'MADE IT BACK FROM CALL OPTC12'
C
C                                                       ERROR MESSAGES
C
      ELSE
          WRITE (IOU,21000) MODE
          WRITE(7,21000) MODE
          RETURN 1
      ENDIF



      RETURN
C
C - Return to previous prompt.
 100  RETURN 2
C-----------------------------------------------------------------
C
20000 FORMAT(/' ',10X,'FINAL RESULTS:'/
     K           11X,'Crack outside geometric bounds:'/
     K           11X,'c = ',G12.4,'  W = ',G12.4)
20001 FORMAT(/' ',10X,'Crack outside geometric bounds: c = ',
     K           G12.4,'  W = ',G12.4)
21000 FORMAT(/' ',10X,
     K       'Program coding error in Sbrtn SITC02:  MODE = ',A4)


 996  FORMAT(A30,5(F8.4,1X))
 999  FORMAT(1x,6(1x,f9.4),I9)
 997  FORMAT(1x,6(1x,e9.4),I9)
 998  FORMAT(7(A10))



      END
```

APPENDIX F

Testing and Analysis for DTA of Fairchild SA226 Main Wing Spar Lower Cap at WS99

FINAL REPORT
SwRI Project No. 06-8520

prepared by

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January 1999

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APPENDIX F TESTING AND ANALYSIS FOR DTA OF FAIRCHILD SA226 MAIN WING SPAR LOWER CAP AT WS99

Final Report

SwRI Project No. 06-8520

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A number of other Southwest Research Institute staff members also contributed to this effort. These individuals include Jon Cutshall, finite element analyses of the complex coupon; Dick Page, fracture surface analyses; Tom Masden, Dale Haines and Darryl Wagar, coupon testing; Isaac Rodriguez, photography; and Terry Sloan, document preparation.

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EXECUTIVE SUMMARY

Southwest Research Institute (SwRI) performed testing and analyses to support a damage tolerance analysis (DTA) effort undertaken by Fairchild Aircraft to extend the useful life of the SA226/SA227 series of aircraft. Fairchild identified the most fatigue critical principal structural element (PSE) on this aircraft as the main wing spar lower cap at wing station 99.0. The lower spar at wing station 99.0 consists of a three-element spar cap comprised of the lower cap, the spar angles and the titanium straps. The lower cap and the spar angles are manufactured from 2014-T6511 aluminum extrusions. The fatigue critical location (FCL) is located in the horizontal legs of the spar angle at the last outboard fastener hole just prior to where the titanium straps end.

Material characterization tests were performed to obtain the basic properties of the 2014-T6511 aluminum extrusion. These included tensile, fracture toughness and fatigue crack growth rate tests. Coupon spectrum tests were performed to generate empirical data to determine whether or not crack growth at this FCL was influenced by load interaction effects (retardation) and to assess the validity of the NASGRO crack growth analysis model used for the DTA of this location. Two specimen geometries were investigated. A simple coupon design using an offset (open) hole in a plate was tested first. This was followed by a more complex coupon geometry designed to represent the load transfer and built-up nature of the actual joint. Load spectra for the coupon tests were derived from the stress spectra developed by Fairchild for this location.

Crack growth analyses were performed using NASGRO for each coupon geometry and demonstrated that very good predictions of the measured data were possible without the use of a retardation model. These results provide confidence in using the NASGRO software and these material properties in the DTA of the 2014-T6511 wing spar components on the SA226/SA227 aircraft. Recommendations were also provided for the final DTA of this location, including the assumption of an initial corner crack in the analysis and the use of a continuing damage analysis to determine the amount of additional life which exists in the part beyond failure of the short ligament.

F1.0 INTRODUCTION

This report summarizes the results of testing and analyses performed by Southwest Research Institute (SwRI) in support of a damage tolerance analysis (DTA) effort undertaken by Fairchild Aircraft to extend the useful life of the SA226/SA227 series of aircraft and to assure the continued airworthiness of these airframes. This class of aircraft have been in production since 1970 and were not designed using damage tolerance techniques. In September 1995, Fairchild Aircraft was funded by the Federal Aviation Administration (FAA) to develop a Supplemental Inspection Document (SID) for the SA226/SA227 aircraft using a damage tolerance approach (FAA Contract No. DTFA03-95-C-00044). The testing and analysis described herein were performed to develop key information for use in the DTA of the most fatigue critical principal structure element (PSE) on the aircraft.

Fairchild identified the most fatigue critical PSE on the aircraft as the main wing spar lower cap at wing station 99.0. This fatigue critical location (FCL) was designed by Fairchild as FCL W1 in their interim SID development report [F1]. A selection and prioritization of FCLs for analysis was performed by Fairchild using a formal ranking procedure developed for use in USAF Structural Integrity Programs [F2]. The results of this ranking process are summarized in Reference [F1].

The geometry and materials of FCL W1 are described in Section F2.0 of this report. Since FCL W1 was the most critical location, SwRI was tasked by Fairchild to generate material property data that would support the DTA of this location. These data consisted of tensile and fracture properties as well as fatigue crack growth rate data and were obtained from specimens excised from representative spar material samples provided to SwRI by Fairchild. A description of these tests and their results are presented in Section F3.0.

In order to validate the predictability of the crack growth models used to represent FCL W1 in the DTA, SwRI performed two sets of coupon spectrum tests on hardware representative of the main spar lower cap at wing station 99.0. Prior to beginning these tests, the spectrum developed by Fairchild for use in the DTA had to be converted to a form suitable for use in the laboratory test machines. Section F4.0 summarizes this process. Details of the two coupon designs (simple and complex) and the spectrum test procedure are presented in Section F5.0 along with results from the tests. Raw data from all the testing performed in this program are contained in the appendices along with additional analyses used to interpret the crack growth measurements.

The results of the coupon tests are compared to analytical predictions made using the NASGRO crack growth analysis software [F3] in Section F6.0 of the report. Finally, a number of recommendations for DTA based on the findings of this program are provided in Section F7.0.

F2.0 MAIN WING SPAR LOWER CAP GEOMETRY AT WS 99 (FCL W1)

A schematic of the geometry of SA226/SA227 main wing spar lower cap at wing station 99.0 (FCL W1) is provided in Figure F2.1. This is a three-element spar cap comprised of the lower cap, the spar angles and the titanium straps and is the primary load carrying member in the wing at this wing station. The lower cap and the spar angles are manufactured from 2014-T6511 aluminum extrusions. The FCL is located in the spar angle at the last outboard fastener hole just prior to where the titanium straps end. This is the highest stressed location in the main wing spar.

Figure F2.2 shows a dimensioned cross section of the lower spar cap at wing station 99.0 indicating the location of the presumed crack for the damage tolerance analysis. A through-thickness crack at the fastener hole is presumed to exist for the DTA. In addition to the high stress levels at this location, this area would be very difficult to inspect as well; hence, FCL W1 was chosen as the FCL on which to perform the coupon spectrum testing in support of the DTA.

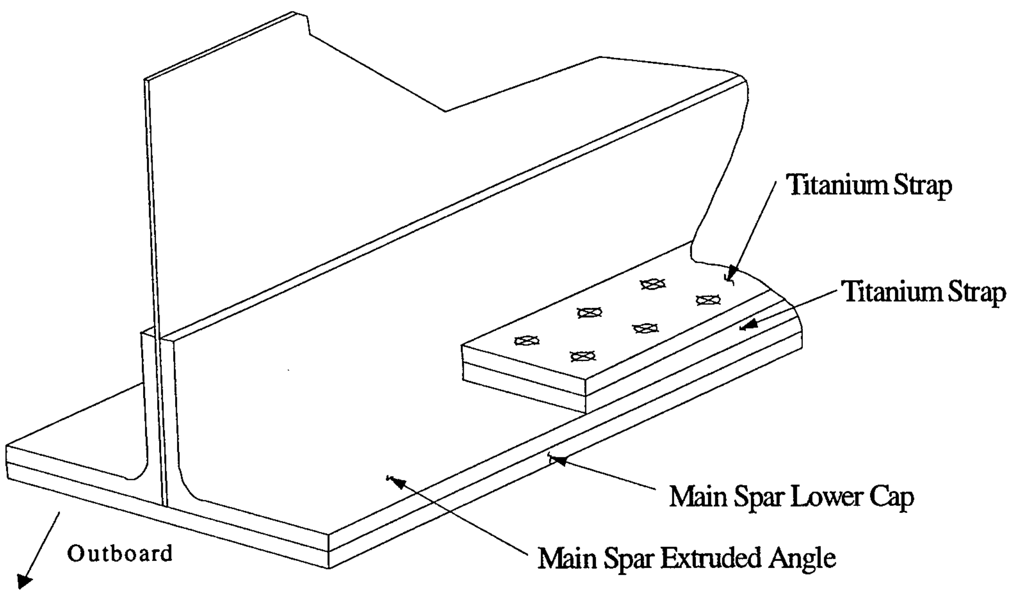
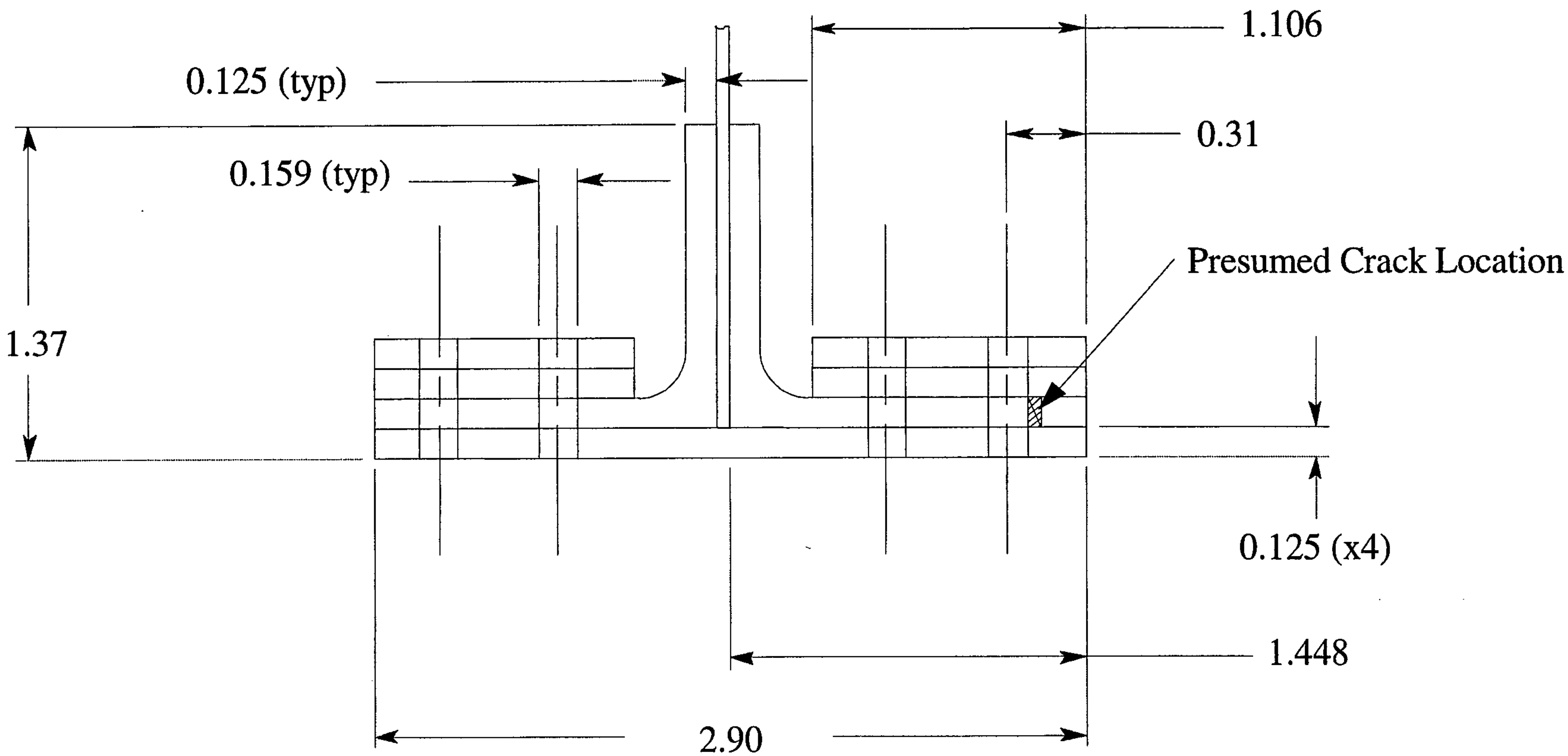


Figure F2.1 FCL W1 — Main Wing Spar Lower Cap at Wing Station 99.0



Note: Dimensions are inches

Figure F2.2 Cross Section of Main Wing Spar Lower Cap at Wing Station 99.0 Showing Location of Presumed Crack for DTA

F3.0 MATERIAL PROPERTIES TESTING

This section describes the material characterization tests performed to obtain basic properties of the 2014-T6511 aluminum extrusion for use in the damage tolerance analysis of the main wing spar lower cap.

F3.1 MECHANICAL CHARACTERIZATION TESTING

Mechanical characterization testing consisted of tensile, fracture toughness, and fatigue crack growth evaluations of the 2014-T6511 aluminum extrusion. The scope of the evaluations is summarized in Table F3.1. Fracture and fatigue testing was performed in the Solid and Fracture Mechanics laboratory at SwRI using a workstation similar to that shown in Figure F3.1. Tensile testing was subcontracted to the Charles C. Kawin Co. (Broadview, Illinois).

Fatigue crack growth testing was performed at different load ratios (denoted as R-ratio and defined as the ratio of minimum to maximum load applied during the fatigue cycle) to determine the influence of mean load level. The nominal R-ratios considered were –0.2, 0.2, 0.5 and 0.8.

F3.1.1 Specimen Geometries

The basic geometries and methods generally conformed to the relevant ASTM test specification [F4]:

- tensile testing: ASTM E8-96a (Standard Test Methods for Tension Testing of Metallic Materials).
- fracture testing: ASTM E399-90 (Standard Test Methods for Plane Strain Fracture Toughness of Metallic Materials).
- FCG rate testing: ASTM E647-95a (Standard Test Methods for Measurement of Fatigue Crack Growth Rates).

Tensile testing specimen blanks were machined into standard specimens with gage lengths of 0.500 inch, as illustrated in Figure F3.2. The tensile properties were determined in the longitudinal orientation for two different types of aluminum extrusion 2014-T6511, that is, a wide plate (specimen ID prefix TE) and angle extrusion (specimen ID prefix TA).

Fracture testing was performed on a sub-thickness (0.125 inch) 1-T plan geometry, compact-tension specimen as illustrated in Figure F3.3. All fracture toughness evaluations were performed on specimens in the L-T orientation and in the thickest geometry possible with the supplied material. This nomenclature implies that the applied loading axis is in the longitudinal direction and the direction of crack advance is in the transverse direction. This orientation is consistent with the crack plane used for the FCL coupons.

Fatigue crack growth rate testing was performed on middle crack tension, M(T), specimens, compact tension, C(T), specimens as well as eccentrically loaded single edge crack tension, ESE(T), specimens with a 1-1/2 T plan geometry. Schematics of the M(T) and ESE(T) specimen geometries are shown in Figure F3.4 and F3.5, respectively. A listing of the test conditions employed is

provided in Table F3.1. The ESE(T) specimen was selected for positive R-ratio fatigue crack growth testing because of non-coplanar crack growth observed in the C(T) specimens during FCG testing. It is not uncommon for 2xxx alloys to exhibit deflected crack growth due to the interaction of texture effects and stress state in the specimen. The ESE(T) specimen design results in a significant decrease in the T-stress (stress parallel to the crack surface) which will tend to increase self-similar cracking and reduce crack deflection [F5].

F3.2 TENSILE TEST RESULTS

A summary of the tensile data obtained for the 2014-T6511 aluminum extrusion is shown in Table F3.2. The tensile test result summary is extracted from the actual data tabulated in Appendix G1 – Material Characterization Properties. Additional details regarding the specifics of all the tensile tests are included in this appendix. All tensile data exceeded the minimums provided for this material as presented in MIL Handbook 5G [F6].

F3.3 FRACTURE TOUGHNESS TEST RESULTS

A summary of the fracture toughness data obtained for the 2014-T6511 aluminum extrusion is shown in Table F3.3. Additional details regarding the specifics of all the fracture tests are included in Appendix G1.

It is important to describe the terminology used to discuss the fracture toughness results. When a fracture test is described as obtaining an invalid plane-strain fracture toughness value (denoted K_q), it does not imply that the test failed or was performed incorrectly. Rather, it implies that during fracture the specimen was not under true plane-strain conditions. The fracture toughness value is then termed K_q as opposed to K_{Ic}, see Table F3.3.

The most notable observation from Table F3.3 is the invalid plane-strain fracture toughness results for this material. The invalidity occurred due to non-plane-strain conditions as evidenced by insufficient thickness and nonlinearity in the load displacement trace. Nevertheless, the toughness levels observed can be considered relevant since the specimen thickness matched the extrusion thickness. Since the actual FCL location thickness used for this material is the same as the fracture test thickness, the toughness values listed in Table F3.3 are more representative of the actual fracture toughness in the less constrained, more plane-stress FCL specimen.

F3.4 FATIGUE CRACK GROWTH RATE TESTING AND RESULTS

F3.4.1 Crack Length Measurement and Crack Growth Test Control Methodology

A special load control method, termed K-control by ASTM, was employed during fatigue crack growth testing to insure that a complete crack growth curve was generated from a single specimen. With this method, the quantity (1/K)(dK/da) is kept constant by changing loads as the test progresses [F7]. This effectively results in a greater ΔK range and minimizes the number of specimens required to construct the crack growth curve from near-threshold to stage III failure. The obvious benefit of K-control methods is that test time is minimized and the number of required specimens is typically reduced. The K-rate (or, more appropriately, the quantity (1/K)(dK/da)) during these crack growth tests was typically between 3.5 and -3.5 in^{-1}.

Both visual (optical traveling microscope) and nonvisual (KRAK gages) crack length measurements were utilized during this crack growth rate characterization testing. The nonvisual crack length measurement technique used was the indirect potential drop method. The potential drop (PD) technique has been used quite successfully for many years to remotely measure crack length [F8]. The PD method utilized in this work is called indirect since the potential output from a KRAK gage bonded to the face of the specimen (illustrated in Figure F3.6) is used to determine crack length. A schematic of the electrical connections to the foil KRAK gage is shown in Figure F3.7.

In practice it is important to calibrate the indirect crack length measurements with the physically measured (e.g., visually measured) crack lengths to achieve the highest level of accuracy. This post-test correction uses a linear scheme based on a minimum of two crack length measurements: at the start and near the end of the test [F9]. Although more complicated, multiple degree-of-freedom correction techniques are available, the corrected crack length measurements typically do not usually differ significantly from the simple linear method [F8].

Fatigue crack growth rate curves for each of the four R-ratios tested in this program are provided in Appendix G1. Additional details regarding the specifics of all the fatigue tests are included in this appendix. For all tests, the repeatability of the replicate testing was quite reasonable. All fatigue testing was performed in laboratory-air conditions.

F3.4.2 Modeling of Fatigue Crack Growth Rate Data

Fatigue crack growth data obtained in this program are compared in Figure F3.8 with the fatigue crack growth curves obtained using the NASGRO crack growth equation and parameters obtained from the NASGRO material database [F3]. As shown in Figure F3.8, the NASGRO curves do not match the test data obtained in the current work. Note, however, that the NASGRO material constants were obtained from testing performed on 2014-T6 plate and sheet and not 2014-T6511 extrusion.

Preliminary crack growth analyses for FCL W1 were performed by Fairchild using the 2014-T6 plate and sheet parameters in the NASGRO material database. Clearly, use of these parameters will overestimate the crack growth rate in spectrum crack growth predictions. Therefore, an iterative process was performed with the parameters so as to produce a best fit to the 2014-T6511 extrusion experimental data obtained in this program. The results of this process are shown in Figure F3.9 along with the revised NASGRO parameters.

Given the original and modified values for the NASGRO parameters, it is worthwhile to compare the experimental crack growth data to predictions made using the NASGRO model. A life ratio can then be determined for each test as defined by the ratio between experimental and predicted crack growth results N_{expt}/N_{pred}. Based upon past experience, a life ratio between 0.5 and 2.0 implies an excellent prediction of the total life results.

The life ratios for the four different load ratios are shown on Figure F3.10 and Table F3.4. Results obtained using the original NASGRO parameters did not match the recorded data particularly well for any of the load ratios considered. The modified NASGRO constants proved relatively effective in predicting the experimental data.

Table F3.1 Material Characterization Tests Performed on Aluminum Alloy 2014-T6511 Extrusion

Property Test	Specimen ID	Specimen Type	Orientation	Load Ratios (R-ratios) Examined			
				-0.2	0.2	0.5	0.8
Tensile	TE-1 *to* TE-4	rectangular	L				
	TA-1 *to* TA-3	rectangular	L				
Fracture Toughness	FC-1 *to* FC-4	C(T)	L-T				
Fatigue Crack Growth	CM-1 *to* CM-3	M(T)	L-T	✓			
	CC-1	C(T)	L-T		✓		
	CE-3 *to* CE-4	ESE(T)	L-T		✓		
	CE-1 *to* CE-2	ESE(T)	L-T			✓	
	CE-5 *to* CE-6	ESE(T)	L-T				✓
	CC-2	C(T)	L-T				✓

Table F3.2 Monotonic Tensile Test Data Obtained for the 2014-T6511 Material

Material	Orientation	Spec. ID	σ_{YS}, ksi	σ_{TS}, ksi	ε, %	RA, %	E, 10^3 ksi
2014-T6511 extrusion	Longitudinal	TE-1	60.7	66.4	10.0	24.2	10.45
		TE-2	62.2	66.8	10.5	27.0	10.75
		TE-3	61.2	65.9	11.0	23.1	10.73
		TE-4	55.8	66.3	11.5	29.2	10.93
		TA-1	61.7	65.6	10.0	20.6	11.74
		TA-2	61.3	65.4	10.5	25.5	11.25
		TA-3	62.1	64.9	11.0	33.4	11.03
average →			**60.7**	**65.9**	**10.6**	**26.1**	**10.98**
MIL HNDBK 5G min. →			**55.0**	**65.0**	**8.0**		**10.50**
NASGRO (2014-T6) →			**65.0**	**74.0**			

Table F3.3 Fracture Toughness Data Obtained for the 2014-T6511 Material

Material	Form	Thickness (in)	Orientation	Specimen ID	Kq (ksi√in)	Valid?
2014-T6511	*extrusion*	0.121	L-T	FC1	35.3	no[1]
		0.123	L-T	FC2	39.7	no[1]
		0.121	L-T	FC3	43.7	no[1]
		0.121	L-T	FC4	40.5	no[1]
				average →	***39.8***	
				MIL HNDBK 5G min. (2014-T651 plate) →	***19.0***	***(valid K_{Ic})***
				NASGRO (2014-T6) →	***27.0***	***(K_{Ic})***

[1] invalid due to insufficient thickness, and $P_{max}/P_Q > 1.10$

Table F3.4 Comparison Between the Experimental and NASGRO Predicted Crack Growth for All FCG Tests

NASGRO Parameters								R-ratio	Life Ratio Range (N_{expt}/N_{pred})	Comments
C	n	p	q	ΔK_0	K_c	S_{max}/σ_0	α			
3.5E-8	2.8	0.5	1.00	2.70	51.8	0.3	1.5	-0.2	1.10 – 3.42	original NASGRO parameters
								0.2	11.23 – 21.77	
								0.5	5.23 – 7.90	
								0.8	2.11 – 5.65	
2.0E-9	3.7	0.5	1.00	2.70	51.8	0.3	2.0	-0.2	0.23 – 1.00	modified NASGRO parameters
								0.2	2.97 – 5.21	
								0.5	0.91 – 1.54	
								0.8	0.20 – 0.78	

Note: In NASGRO, K_c is computed using input values of yield strength, σ_{YS}, plane strain fracture toughness, K_{Ic}, and thickness, t. The NASGRO values of σ_{YS} (65.0 ksi) and K_{Ic} (27 ksi $\sqrt{in}$) were used in the analyses to fit the data and compute a K_c of 51.8 ksi $\sqrt{in}$ as shown above.

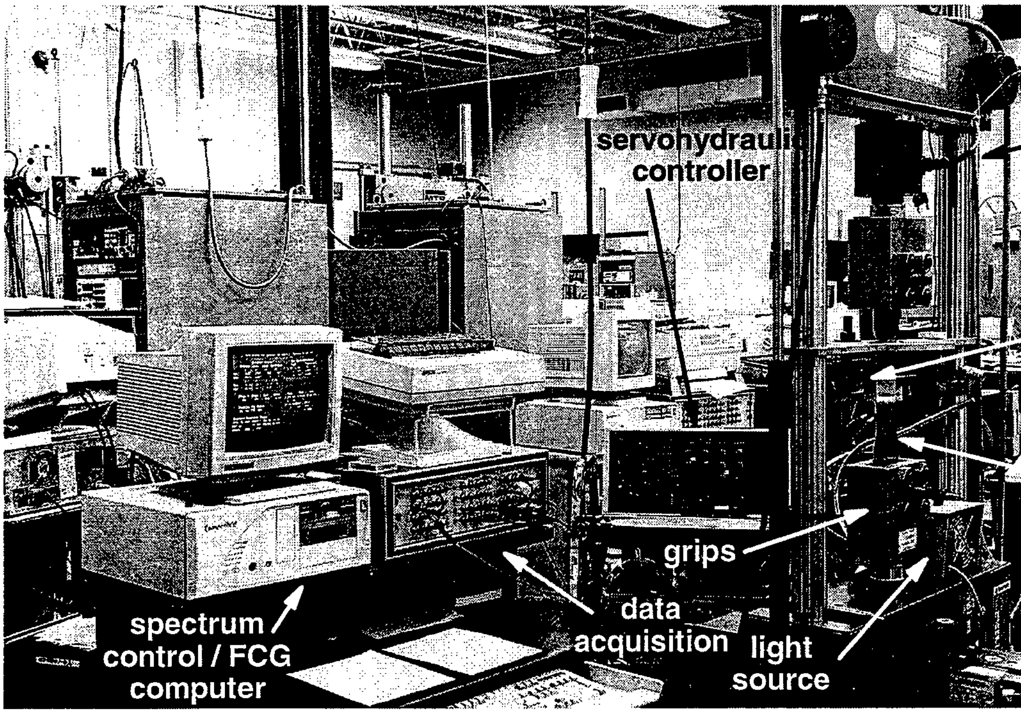
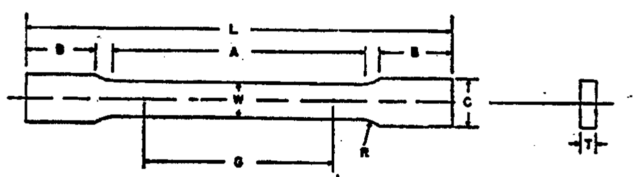


Figure F3.1 Typical Fatigue and Fracture Test Station in the SwRI Solid and Fracture Mechanics Laboratory

E 8



Dimensions			
	Standard Specimens		Subsize Specimen
	Plate-Type, 1½-in. Wide	Sheet-Type, ½-in. Wide	¼-in. Wide
	in.	in.	in.
G—Gage length (Notes 1 and 2)	8.00 ± 0.01	2.000 ± 0.005	1.000 ± 0.003
W—Width (Notes 3 and 4)	1½ + ⅛, −¼	0.500 ± 0.010	0.250 ± 0.005
T—Thickness (Note 5)		thickness of material	
R—Radius of fillet, min (Note 6)	1	½	¼
L—Over-all length, min (Notes 2 and 7)	18	8	4
A—Length of reduced section, min	9	2¼	1¼
B—Length of grip section, min (Note 8)	3	2	1¼
C—Width of grip section, approximate (Notes 4 and 9)	2	¾	⅜

Specimen size used for tensile testing

Figure F3.2 Tensile Specimen Geometry Utilized for Assessing the Tensile Strength of the Aluminum Extrusion (Extracted from ASTM Standard E8 [F1])

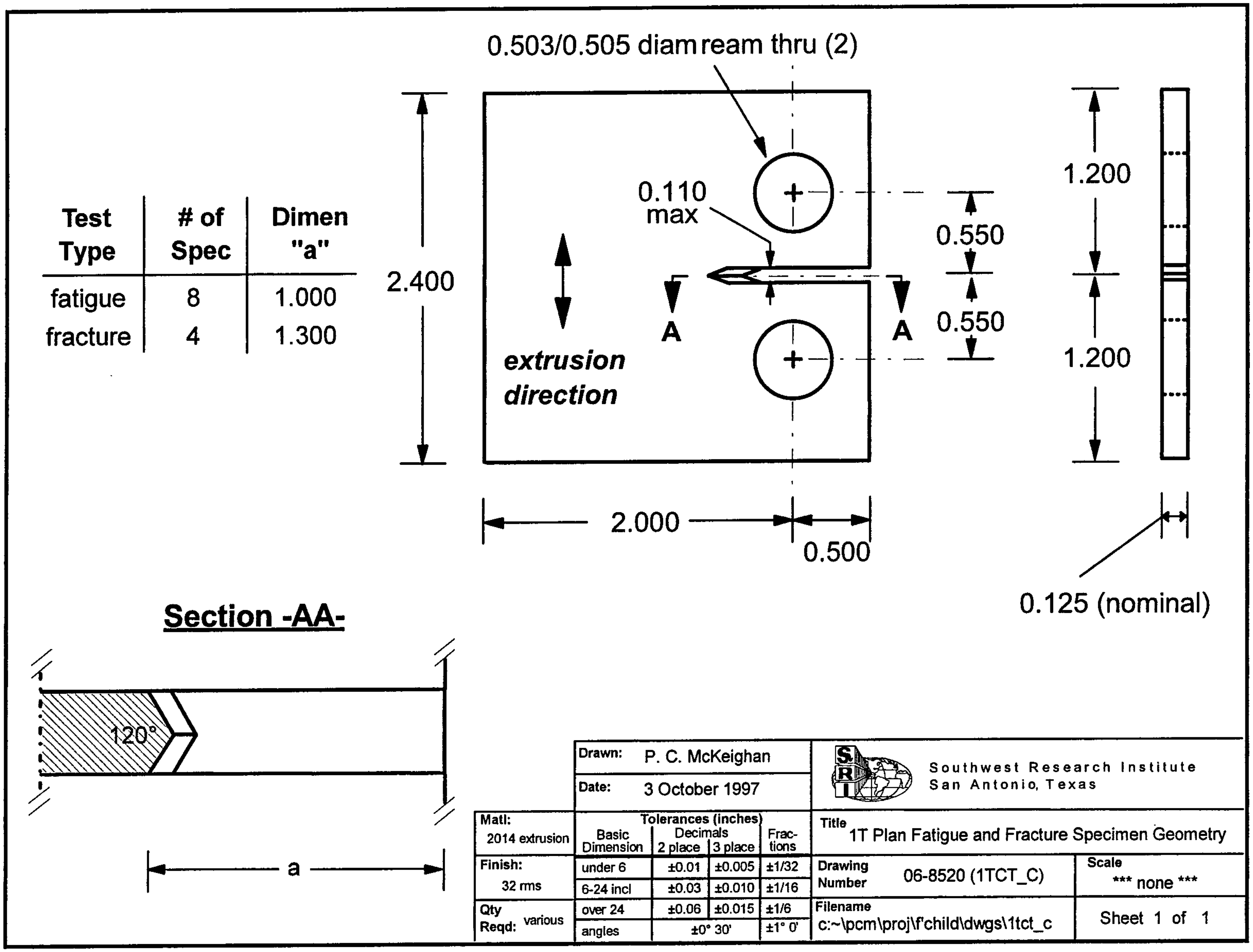


Figure F3.3 Design for the 1-T Plan Geometry Compact Tension Fracture and Fatigue Crack Growth Specimens

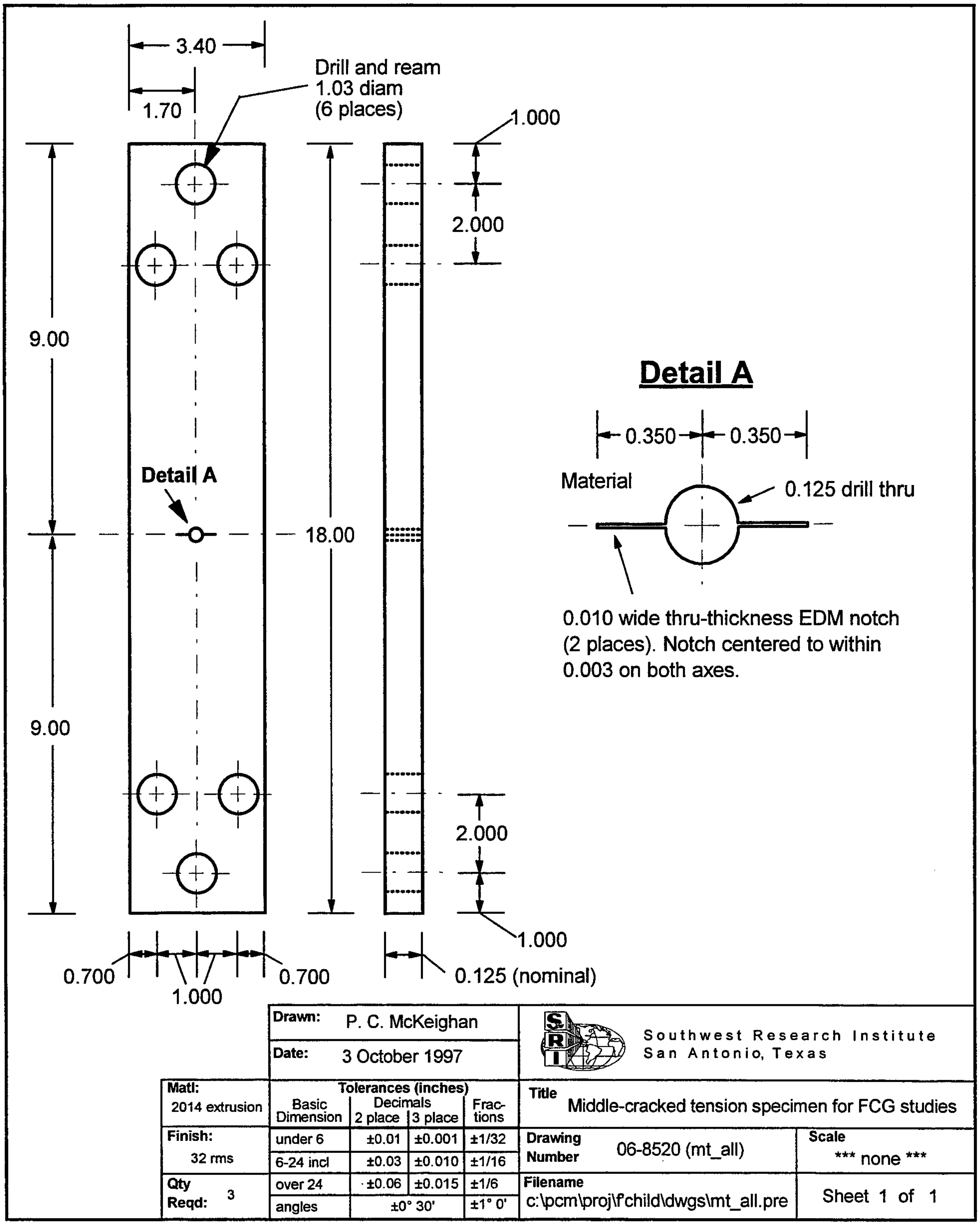
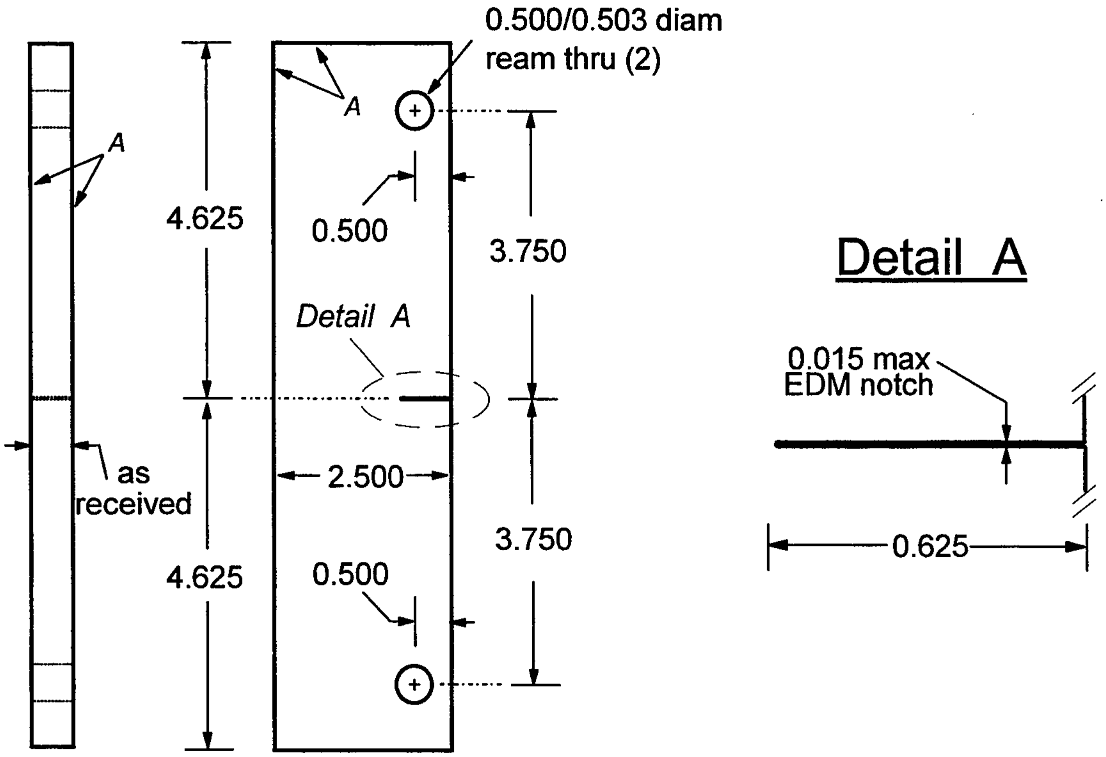


Figure F3.4 Design for the Middle Crack Tension Specimen for Fatigue Crack Growth Studies



Note 1 A-surfaces perpendicular and parallel (as applicable) to within 0.006, TIR.

Note 2 All surface finishes 32 RMS except loading hole bore (16 RMS).

Note 3 The intersection of the tips of the machined notch with the specimen faces shall be equidistant from the top and bottom edges of the specimen to within 0.015.

Material	Number of Specs	Specimen ID's
2014-T6511 extrusion	6	CE1 to CE8

	Drawn: F. J. McMaster				Southwest Research Institute San Antonio, Texas	
	Date: 12 December 1997					
Matl: 2014-T6511	Tolerances (inches) Basic Dimension	Decimals 2 place	Decimals 3 place	Fractions	**Title** Extended compact tension, EC(T), specimen for fatigue crack growth testing	
Finish: 32 rms	under 6	±0.01	±0.005	±1/32	**Drawing Number** 06-8520 (15TECT_C)	**Scale** *** none ***
	6-24 incl	±0.03	±0.010	±1/16		
Qty Reqd: 8	over 24	±0.06	±0.015	±1/6	**Filename** c:~\fraser\swri\projects\fairchd\15tect_c	Sheet 1 of 1
	angles	±0° 30'		±1° 0'		

Figure F3.5 Design for the 1-T Plan Geometry Eccentrically Loaded Single-Edge Crack Tension Specimen for Fatigue Crack Growth Studies

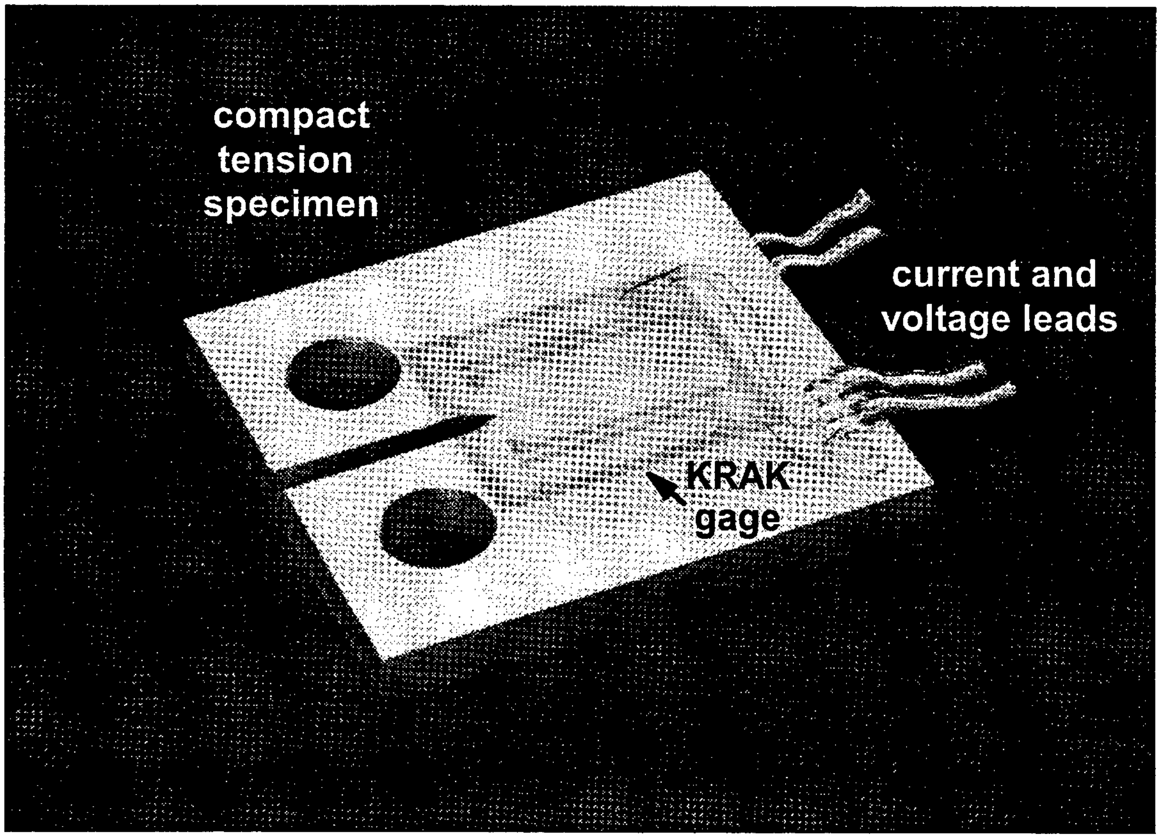


Figure F3.6 Typical Krak Gage Setup with Gage Bonded to Face of C(T) Specimen

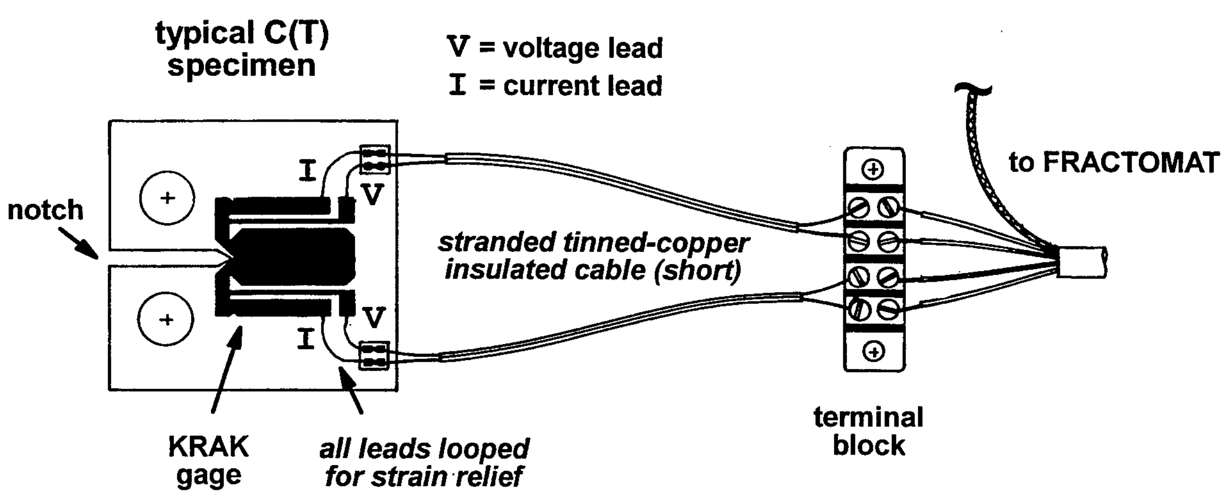


Figure F3.7 Schematic of Connections Required on a KRAK Gage on a C(T) Specimen

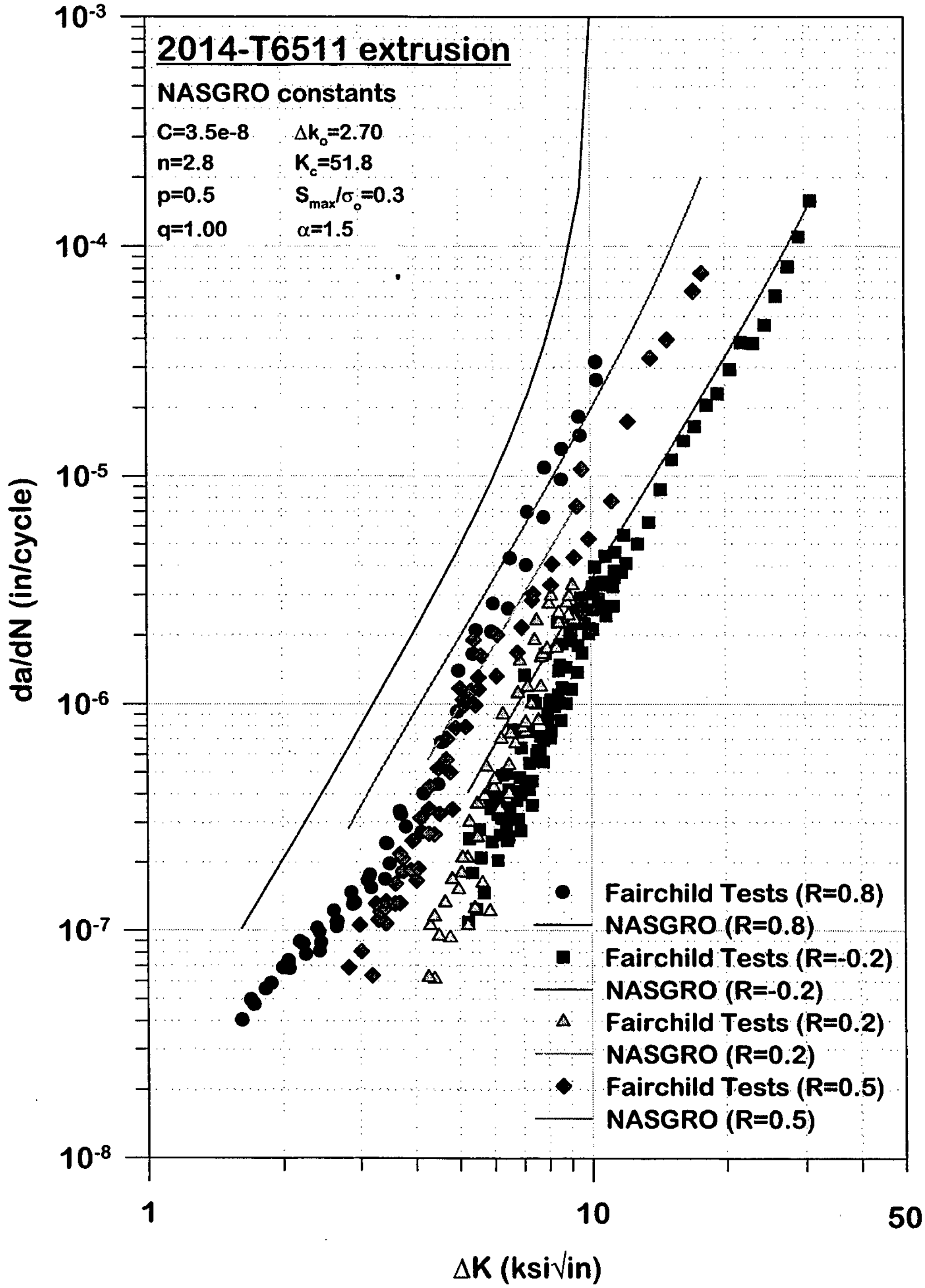


Figure F3.8 FCG Data for the 2014-T6511 Extrusion Compared with the NASGRO Output (Using NASGRO Material Constants)

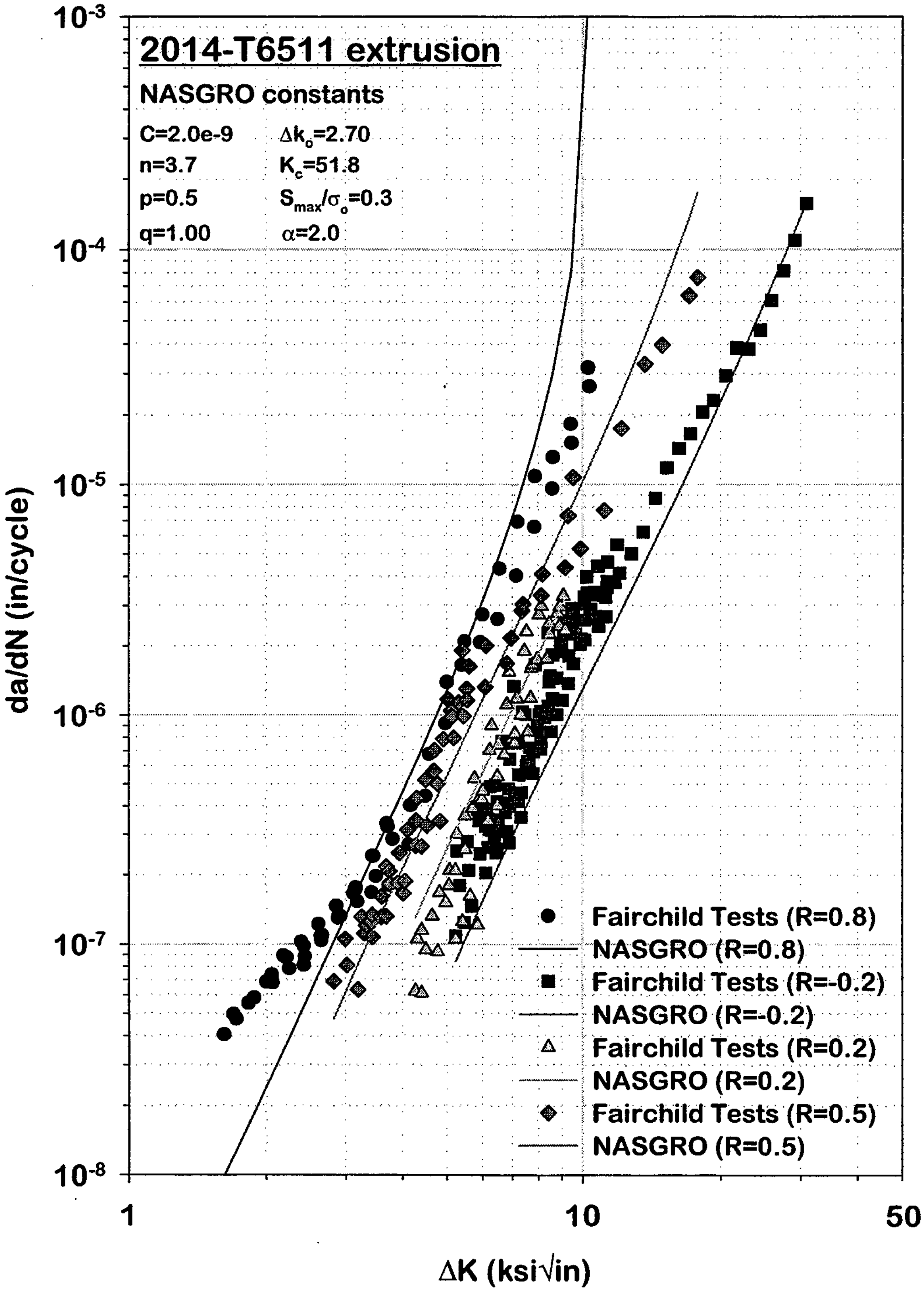


Figure F3.9 FCG Data for the 2014-T6511 Extrusion Compared with the NASGRO Output (Using Modified NASGRO Material Constants)

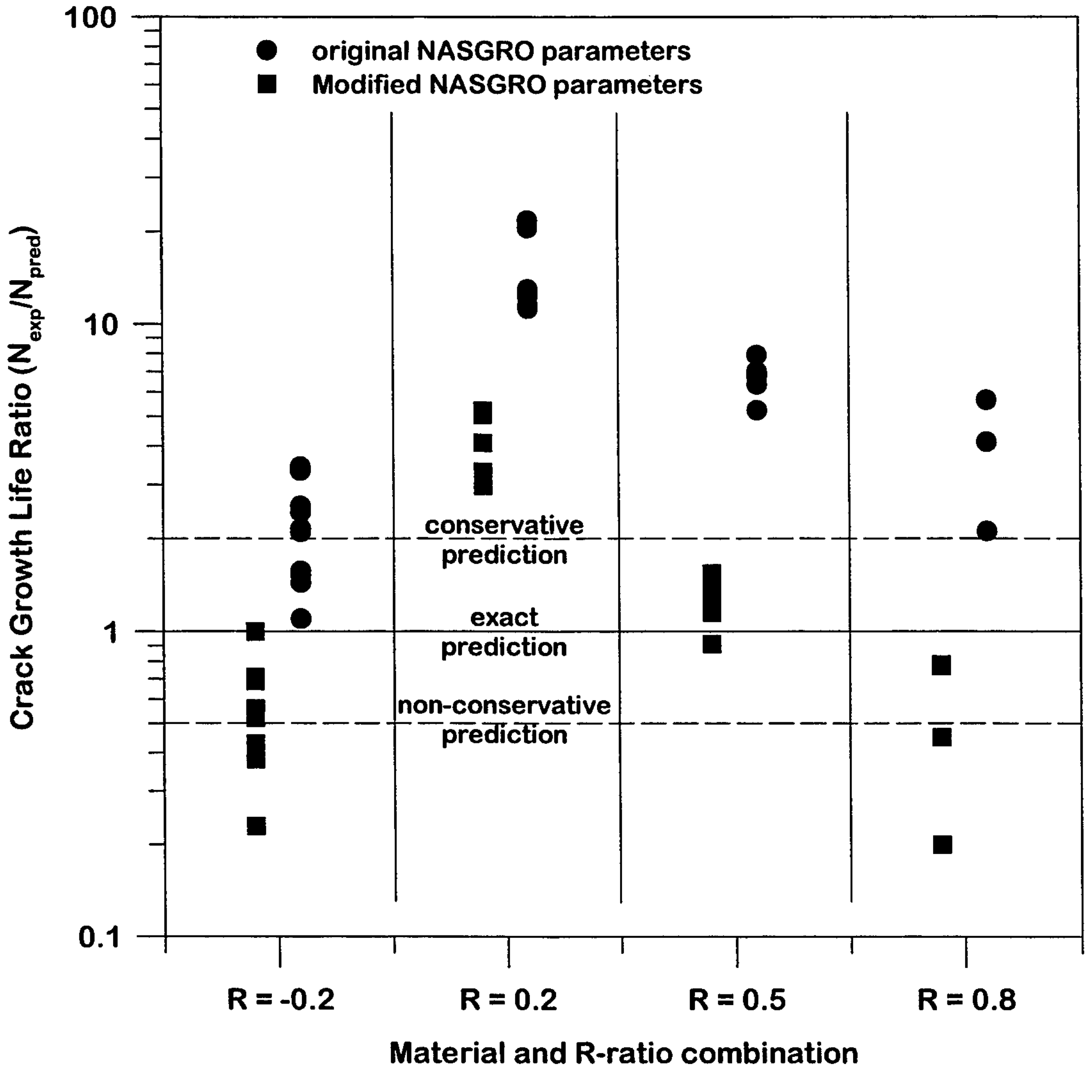


Figure F3.10 Ratio of Experimental to Predicted Lives of FCG Test Specimens Using the NASGRO Model Parameters

F4.0 DEVELOPMENT OF SPECTRUM FOR FCL W1 COUPON TESTS

Fairchild developed load spectra for the SA226/SA227 aircraft as described in Reference [F1]. These loads were then, in turn, used by Fairchild to develop stress spectra at fatigue critical locations using the results of in-flight strain surveys and earlier full-scale fatigue tests. This section of the FCL W1 testing and analysis report describes how SwRI converted the stress spectra used by Fairchild for their DTA of FCL W1 to a spectra suitable for use in the coupon testing machines.

The original analysis spectrum provided to SwRI by Fairchild for FCL W1 was a 5.5 hour spectrum consisting of one short flight (0.5 hour), three medium length flights (1.0 hour each), and one long flight (2.0 hours). Each flight was comprised of three loading blocks: taxi, gust, and landing. The taxi and landing blocks were identical for all flights. Differences in the number of cycles contained in the gust blocks distinguished the three flight types from each other. Each spectrum block contained a set of load steps with a (noninteger) number of occurrences, N, and minimum and maximum loads (F_{min}, F_{max}) corresponding to specific g-levels. In addition, a constant load value, F_{mean}, was supplied such that it was added to each load step to increase the mean load level.

The damage tolerance analysis (DTA) of this FCL uses NASGRO model TC03, a through-crack emanating from a hole in a plate subject to both a remote tension load and a pin load [F3]. Fairchild provided scale factors converting the spectrum file loads data to tension stresses and bearing stresses. Thus, in the course of executing NASGRO, the stresses are computed as follows:

$$S_{0,\,\mathrm{min}} = (F_{\mathrm{min}} + F_{\mathrm{mean}})\, SF_{\mathrm{t}} \quad \text{and} \quad S_{0,\,\mathrm{max}} = (F_{\mathrm{max}} + F_{\mathrm{mean}})\, SF_{\mathrm{t}} \tag{1}$$

$$S_{3,\,\mathrm{min}} = (F_{\mathrm{min}} + F_{\mathrm{mean}})\, SF_{\mathrm{b}} \quad \text{and} \quad S_{3,\,\mathrm{max}} = (F_{\mathrm{max}} + F_{\mathrm{mean}})\, SF_{\mathrm{b}} \tag{2}$$

where S_0 and S_3 are the tension and bearing stresses, respectively (in the NASGRO notation), and SF_{t} and SF_{b} are the scale factors converting the spectrum file loads data to tension and bearing stresses, respectively.

The coupon test program was conducted in two phases, using a simple coupon and a complex coupon. The simple coupon was a single plate of aluminum with an offset open hole. The complex coupon was designed to represent the actual spar sandwich structure with two aluminum plates and two titanium plates, fastened together. In order to develop a spectrum for testing in the laboratory it was necessary to convert the analysis spectrum described above to a test spectrum that (1) was comprised of integer cycle numbers and (2) was represented in terms of uniaxial tension loads.

To convert the spectrum such that it contained only integer cycles, the number of cycles were multiplied by a factor of 100 and rounded off. This resulted in a 550 hour spectrum; however, the rounding off to integer cycle numbers resulted in the loss of a number of fractional cycles. These cycles were recovered by creating a select few make-up cycles and manually inserting them into the spectrum file. A total of seven make-up cycles were added, four gust and three landing. The magnitude of these cycles was determined using a weighted average technique based on the

fractional cycle amount lost during the round-off process and the corresponding magnitudes of those fractional cycles.

It was then necessary to convert the tension and bearing loads to remote tension loads to develop an equivalent tension test spectrum. This computation was made using the overall force balance on the coupon:

$$F_{eq} = S_0(Wt) + S_3(Dt) \tag{3}$$

where W is the coupon width, D is the hole diameter, t is the thickness, and S_0 and S_3 are computed as equations 1 and 2.

An analysis of the open-hole simple coupon was performed using the original spectrum (with tension and bearing loads) and compared to results obtained using the remote equivalent tension load spectrum. As expected, the life was somewhat less for the equivalent tension load spectrum case. Thus, the tension only spectrum was scaled up by a factor of 1.06 to approximate the life predicted by the pin load plus tension load analysis.

For the complex coupon tests, the same equivalent tension load spectrum was used; however, it was scaled up by a factor of 1.16 based on the results of a strain survey in order to achieve the desired peak spectrum stress of approximately 11 ksi at the test section of the coupon. This target value of 11 ksi was chosen based on the 2-g stresses for this location listed in Table D-11 of Reference [F1]. The analysis of the complex coupon uses the spectrum comprised of the tension and bearing loads since the hole is loaded by the fastener in the complex coupon test.

Comparisons between coupon test results and corresponding analytical predictions of crack growth must obviously use the same (test) spectrum. However, it is important to emphasize that the spectra developed for the simple and complex coupons were only developed for use in the coupon tests and should not be used for the final DTA. The original analysis spectrum should be used in the DTA.

F5.0 COUPON SPECTRUM TESTING

The objectives of the coupon spectrum testing were to generate empirical data that could be used to (1) determine whether or not FCL W1 exhibited any effects of load interaction (retardation) on crack growth behavior and (2) to assess the validity of the NASGRO crack growth analysis model used for the DTA of this location. The test coupon geometries used to simulate FCL W1 as well as the test procedures used to perform the spectrum crack growth testing are described in this section.

The FCL W1 geometry is a sandwich structure comprised of the titanium straps and the aluminum spar angles and lower cap as shown in Figure F2.1. Based on stress analyses performed by Fairchild, the most critical areas of this joint are the last fastener holes at the outboard end of the titanium straps. Refer to Figures F2.1 and F2.2. The short ligament length in the horizontal leg of the spar cap is the worst case location at which a through-thickness crack is presumed to exist for the purposes of a damage tolerance analysis. In the coupon tests, a through-thickness crack was inserted at this location using an EDM procedure as described below.

The coupon designs used in this program were jointly developed by SwRI and Fairchild engineers. Fairchild Aircraft provided the aluminum and titanium material for manufacture of the coupons. Fairchild also drilled the fastener holes and assembled the complex specimens. SwRI was responsible for installation of the crack growth measurement gages and the strain gages.

The design of the coupons was based on three factors: (1) the availability of material stock at Fairchild; (2) the constraints of the test equipment (grips, fixtures, etc.); and (3) the geometry of the actual FCL W1 at WS 99. Generally, when performing coupon spectrum tests, it is desired to design a coupon that as closely as possible represents the actual geometry; however, as a practical matter, it is rare that the coupon geometry will exactly match the actual FCL geometry. Therefore, taking the three factors listed above into account, coupon design for spectrum testing must focus on developing a geometry that represents as best as practical the salient features of the actual FCL. Therefore, differences exist between the coupon design and the actual structure; however, the coupons do represent the general features of the FCL at WS 99.

Due to the complexity of this joint, it was deemed prudent by SwRI and Fairchild to implement a two-phase approach to the coupon spectrum testing for FCL W1. A simple coupon design using an offset (open) hole in a plate was tested first. This was followed by a more complex coupon geometry designed to represent the load transfer and built-up nature of the actual joint. Note that in the complex geometry the crack is not visible from the exterior of the coupon and that a fastener fills the hole. Therefore, as will be described, the simple coupon tests served as preliminary studies to investigate the general spectrum crack growth behavior in this material and to establish the viability of the crack growth measurement technique planned for use in the complex geometry where the crack growth was not directly visible.

In this section of the report, a general overview of the test procedures is first presented followed by specific details of each coupon design and test setup along with the results obtained. Comparisons to analytical predictions are presented in Section F6.0.

F5.1 GENERAL TEST PROCEDURES

The test procedures used to perform the spectrum crack growth (SCG) testing were developed from many years of experience performing similar testing at SwRI. Although there is no specific industrywide standard related to SCG testing, the methods used are derived from the ASTM E647 standard for fatigue crack growth testing [F4]. Spectrum loads were applied in the frequency range of 5-20 Hz. The actual loading frequency used depended upon the response and controllability of the specific servo-hydraulic frame employed.

The spectrum crack growth test matrix for FCL W1 is shown in Table F5.1. This tabular representation of the matrix is organized in terms of the two different coupon geometries: simple and complex.

F5.1.1 Spectrum Test Methods and Control

The coupon spectrum tests utilized closed-loop, servohydraulic testing systems specially designed to apply variable amplitude waveforms. The stress spectra were electronically stored in a format compatible with SwRI's computer software/hardware systems. The closed-looped control systems used in the test systems insure that the peak load levels are applied to the specimen during cycling. One of the key features of the systems used in the SwRI laboratory is a command/feedback certification procedure utilizing modification of the command signal based on the historical feedback performance during the last spectrum pass. This assures the most accurate and consistent loading of the specimen during testing.

F5.1.2 Spectrum Markerband Procedure

In addition to nonvisual measurements of crack length obtained using KRAK gages, a spectrum marking procedure was used to provide markerbands on the fracture surface to verify and posttest correct the nonvisually measured crack lengths. The marking procedure was tested using the simple geometry SCG specimens to insure that the technique did in fact mark the fracture surface consistently and hence could be used effectively on the complex coupon geometry. With the marking procedure, a number of markerbands, each about 0.003-0.005 inch wide, are placed on the fracture surface with an average of 15-20 markerbands placed on the fracture surface over a ligament length of 0.295 inch. The marking procedure involved applying constant amplitude loading at a high R-ratio so as to induce a different fracture surface appearance. The markerbands were typically applied at a peak load of 80 percent of peak spectrum load and an R-ratio of 0.6.

Due to the premature failure of the KRAK gages in the second test performed on the simple geometry, it was deemed vital to use the markerband procedure on the complex coupon geometries. Since the plate containing the crack was not visible from the exterior of the complex specimen, this insured that crack length measurements could still be made (from the fracture surface) in the event that the KRAK gages failed during the test.

F5.2 SIMPLE COUPON GEOMETRY

F5.2.1 Coupon Design

The simple coupon geometry is shown in Figure F5.1. The FCL in the simple coupon geometry is defined as a through crack at a 0.19-inch-diameter offset hole having a 0.35-inch edge distance. The thickness of the coupon was 0.125 inch. EDM flaws were introduced into the coupons to facilitate the pre-cracking process prior to spectrum loading. All EDM flaws were through-thickness with a nominal width of 0.006 inch and a surface length of 0.025 inch.

F5.2.2 Test Setup and Coupon Pre-cracking

Pre-cracking was performed in order to precondition and sharpen the EDM flaw into a fatigue crack prior to spectrum testing. In the strictest sense, the EDM flaw is initially machined into the specimen. Although crack-like in nature, it would not act enough like a real fatigue crack to insure good initial data. Therefore, prior to spectrum testing, blocks of constant amplitude loading were applied to initiate and grow a fatigue crack from the EDM flaw. Experience has shown that a minimum of approximately 0.010-0.015 inch of constant-amplitude fatigue crack growth is required.

The goal during the simple coupon geometry pre-cracking was to grow a fatigue crack from the tip of the EDM flaw to a total length of 0.050 inch measured from the edge of the hole. Pre-crack load levels were kept as low as practical, typically less than 75-80 percent of the peak spectrum load. Constant-amplitude cycles at an R-ratio of 0.1 were employed during pre-cracking.

A photograph of the simple geometry coupon gripped in the servohydraulic load frame is shown in Figure F5.2. A fixed constraint, or antibuckling guide, was attached to the main clevis to provide support for a variety of teflon-coated movable, or free, constraints (these antibuckling fixtures are not shown in Figure F5.2). The movable constraints located between the fixed constraint and test section were free to move in a vertical direction only. Horizontal constraint was achieved through set screws that were located in the fixed constraint.

Visual and nonvisual crack length measurements were recorded. Two different sized gages were used during the simple coupon geometry testing: KG-BH5616-X08 (short ligament) and KG-BH5616-X15 (long ligament). Due to the length of the short ligament in the simple coupon geometry (0.256 inch), part of the -X08 KRAK gage overhung the edge of the coupon and therefore needed to be supported by an extension plate. This type of arrangement was also used for the complex geometry tests and, hence, a more in-depth explanation of this arrangement is provided in Section F5.3.

F5.2.3 Results

Two tests were performed using the simple coupon geometry as indicated in Table F5.1. In general, given a specific crack length envelope, if the cycles, or spectrum flight hours (SFHs) corresponding to the growth, are within ±15 percent, the test is considered repeatable. This level of accuracy is based upon extensive SwRI spectrum testing experience. The test-to-test repeatability is dependent upon the coupon geometry (complexity), inherent material variability, crack shape and errors in crack length measurement.

Results obtained for the simple geometry coupons tested under flight spectrum conditions are shown in Figure F5.3. The data plotted in Figure F5.3 were obtained from visual measurements obtained using a microscope. Due to the failure of a KRAK gage on one of the coupons (SS-2), only nonvisual crack length measurements were obtained for one of the two tested coupons. Crack length measurements for each of the simple coupon geometry tests are provided in Appendix G2 – Spectrum Crack Growth Tests. The fracture surfaces for these coupons are shown, with test parameters, in Figure F5.4.

The results shown in Figures F5.3 and F5.4 for the simple coupon geometry tests can be summarized as follows:

- Total coupon life varied from 92 to 133 kSFH. Hence the tests exhibit poor repeatability.

- The crack growth curves observed (Figure F5.3) were concave up in accordance with typical behavior.

- The pre-cracked ligament failed prior to the initiation of a crack on the opposite side of the hole. Spectrum flight hours to failure of the short ligament ranged from 58 to 101 kSFH.

- Initiation of a crack on the non pre-cracked side of the hole took approximately 16 to 24 kSFH following failure of the short ligament.

- The time spent cracking the longer (uncracked) ligament was approximately 10 to 16 kSFH.

- For coupon ID (SS-2), both KRAK gages failed at the extension tab-coupon interface at approximately 37 kSFH.

- The marking procedure used on the simple geometry tests appeared to work well.

As illustrated in the micrographs in Figure F5.4, vastly different fracture surfaces were observed for the two simple geometry coupon tests. This necessitated further investigation as this may be the reason for the large differences in spectrum flight hours for the two coupons. Test coupon SS-2 had a rough fracture surface with areas of large cleavage facets and prominent striations. Conversely, the fracture surface of test coupon SS-3 was relatively flat with only the applied markerbands visible on the fracture surface. Photographs of the macroscopic grain structure of both specimens are shown in Figure F5.5. Crack propagation in both coupons was found to be transgranular; however, a dramatic difference in grain size for the two coupons was noted.

The contrast in the SCG lives of the two simple geometry tests can be explained in terms of the differences in their grain structure. Whereas dislocations easily shear the small grains in SS-3, the larger grains in SS-2 form obstacles to dislocation motion with the result that the dislocations loop around the grains and bypass them. Thus, the principal cause of the apparent differences in the spectrum crack growth response of the two microstructures is expected to be crack deflection and the attendant roughness-induced closure.

F5.3 COMPLEX COUPON GEOMETRY

F5.3.1 Coupon Design

The complex coupon design is shown in Figure F5.6. The complex geometry is a multiple-layered joint that represents the actual FCL with fastener loading, multiple load paths, and tension-bending. Testing of this joint required a high level of instrumentation, with strain gages (Figure F5.6) applied to various components of the joint to assess the overall loading and load paths in the structure. The test section of the coupon that contained the crack is labeled "E" in Figure F5.6. The FCL in the complex specimen is defined as a through crack at a 0.16-inch-diameter hole having a 0.375-inch edge distance. Again, the thickness of the test section was 0.125 inch.

F5.3.2 Test Setup and Coupon Pre-cracking

During the pre-cracking phase of testing it was found to be extremely difficult to initiate a crack from the EDM notch (due to the complex nature of the joint and the low constant-amplitude loads applied). Therefore, a multitude of different peak constant amplitude loads and R-ratios were used to successfully initiate a crack and propagate the crack to the required 0.050-inch pre-crack length. The details of the pre-cracking loads and R-ratios used in the complex geometry pre-cracking process are summarized in Table F5.2.

A single sized gage was used during this testing phase: KG-BH5616-X08 (short ligament and middle ligament). Due to the length of the short ligament in the complex geometry (0.295 inch), part of the -X08 KRAK gage overhung the edge of the coupon and therefore needed to be supported by an extension tab. A photograph of the KRAK gages applied to the test section of the joint is shown in Figure F5.7. A photograph of the complex geometry coupon mounted in the servohydraulic load frame is shown in Figure F5.8. Hydraulic grips were used during this testing phase to insure the best load transfer. However, due to the large size (and mass) of the grips, test frequency was limited to a maximum of 10 Hz.

F5.3.3 Strain Survey

An initial strain survey was performed on all complex geometry coupons to measure the relative strain levels reached during loading of the complex joint. Eight strain gages were attached to the coupons and the strain measurements were obtained at 85 percent of the peak spectrum load. A summary of the strain survey results is given in Figure F5.9 as a function of the relative positions of the strain gages. The repeatability of the strain gage measurements for the three complex coupons is quite excellent.

Strain gage numbers 7 and 8 were positioned on the complex coupon such that they matched the location of Fairchild flight test gages 3 and 2, respectively. (Refer to Table D-11 of Reference [F1].) Therefore, the average of gages 7 and 8 was used to scale the spectrum such that a target stress value of 11 ksi was achieved on the lower cap portion of the complex coupon. As discussed in Section F4.0, the scale factor obtained in this fashion was 1.16.

The complex geometry tests were also periodically interrupted to take strain data for a loading and unloading ramp to 85 percent of the peak spectrum load. Representative strain traces

for all three tests and compliance data are provided in Appendix G2. Compliance measurements taken during all three tests showed little difference between loading and unloading and remained constant for the majority of the test duration.

The compliance results can be used to determine both load transfer and bending using the following equations:

$$\text{Load Transfer (\%)} = 100\left(1 - \frac{C_5 + C_6}{C_3 + C_4}\right) \quad (4)$$

$$\text{Bending (\%)} = 100\left(\frac{C_1 - C_2}{C_1 + C_2}\right) \quad (5)$$

where C_i is the calculated compliance value at gage i. The results are shown in Figure F5.10 plotting percent load transfer and percent secondary bending as a function of spectrum flight hour (loading cycle).

The mean load transfer observed for all tests was between 40-42 percent indicating that the titanium straps take approximately 40 percent of the load. The similarity of the responses is remarkable and presumably indicative of uniform joint behavior and fixed clamping. Relative to a pure tensile test, levels of bending were quite high, as expected, and typically averaged 17-20 percent. Bending in the actual wing spar would be expected to be less than that observed in the complex coupon geometry due to the presence of the vertical legs of the spar angles in the actual structure.

F5.3.4 Results

The test results obtained for the complex geometry coupons (CS-1, CS-2, and CS-3) tested under flight spectrum conditions are shown in Figure F5.11. Visual and nonvisual crack length measurements for each of the complex coupon geometry tests are provided in Appendix G2. Premature failure of the KRAK gages did not occur during any of the three complex geometry tests. The fracture surfaces for these coupons are shown in Figure F5.12, with the markerbands clearly visible for all three tests.

The results shown in Figures F5.11 and F5.12 can be summarized as follows:

- Complex geometry tests were terminated after the short ligament failed (or appeared to be completely fractured).
- Short ligament life was measured to be 121, 142, and 201 kSFH.
- Curved crack fronts were observed for all tests. This is indicative of the tension-bending loading obtained during testing of the built-up joint.
- Posttest visual crack length measurements (Figure F5.11) for all tests were shown to be approximately 0.010-0.020 inch greater than those measured using the KRAK gages. This difference is investigated and discussed further in Appendix G2.

Table F5.1 Spectrum Crack Growth Tests and Specimen IDs

FCL Designation	Geometry	Specimen ID	Thickness (inch)	EDM Length (inch)
W1	simple	SS-2	0.1231	0.024
		SS-3	0.1232	0.025
	complex	CS-1	0.1243	0.017
		CS-2	0.1244	0.023
		CS-3	0.1242	0.022

Table F5.2 Pre-Cracking Details for the Complex Geometry Tests

Specimen ID	Number of Cycles	Maximum Precracking Load (% of peak spectrum load = 4520 lbs)	R-ratio
CS-1	51,000	55	0.1
	83,000	65	0.1
	100,000	75	0.1
	100,000	95	0.1
	250,000	100	0.1
	65,000	100	-1.0
	3,978	100	0.1
	107,400	80	0.1
CS-2	100,000	100	0.0
	49,320	100	-1.0
	78,102	80	0.0
CS-3	29,070	100	-1.0
	3,000	80	0.0

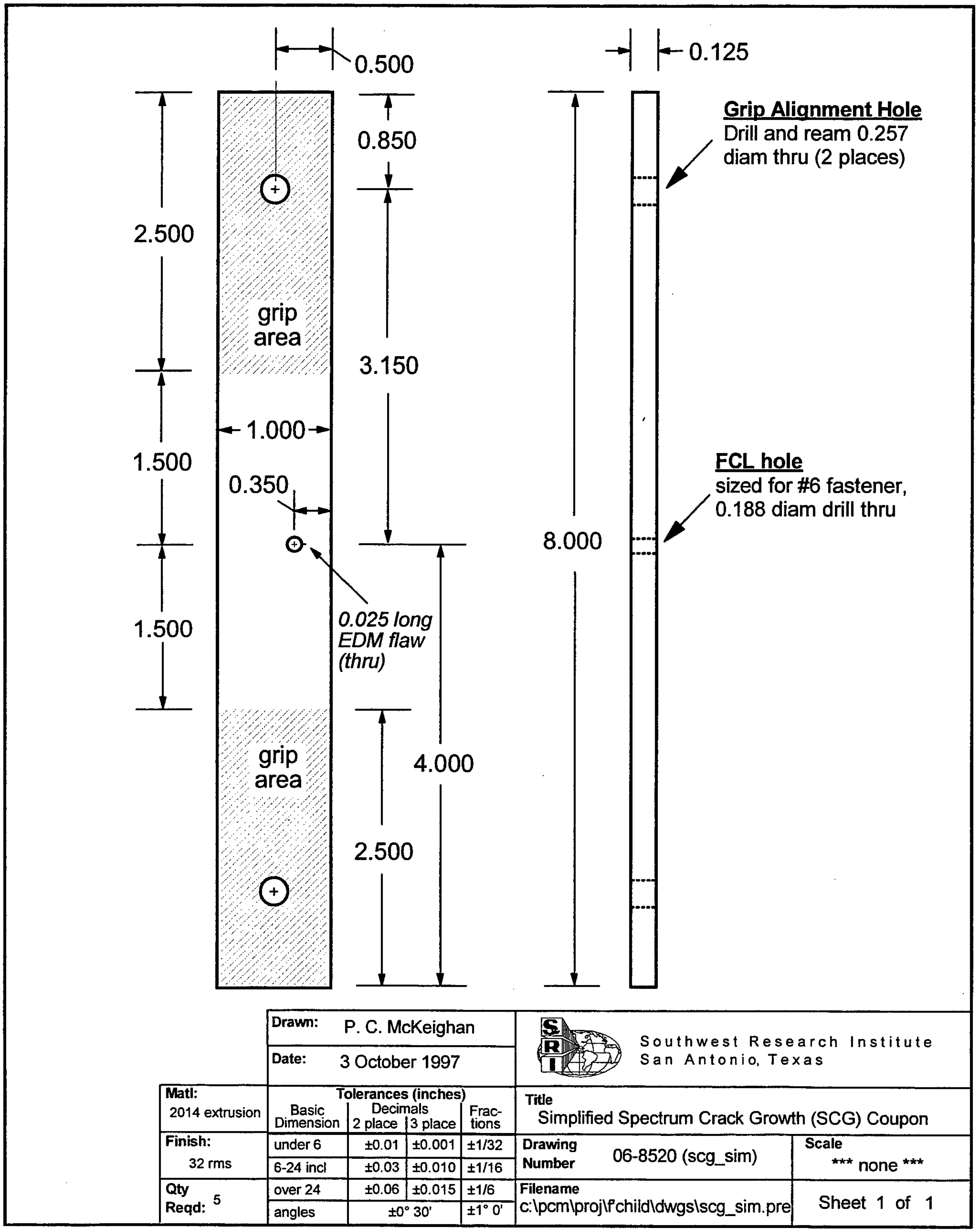


Figure F5.1 Design for the Simple Geometry Coupon for Spectrum Crack Growth Studies

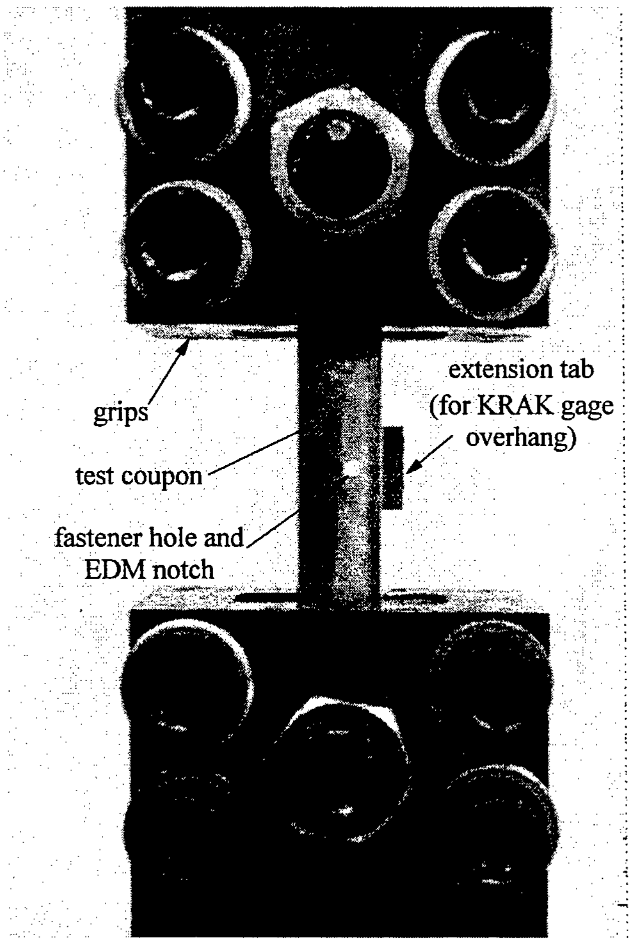


Figure F5.2 Representative Test Setup for the Simple Geometry Coupon

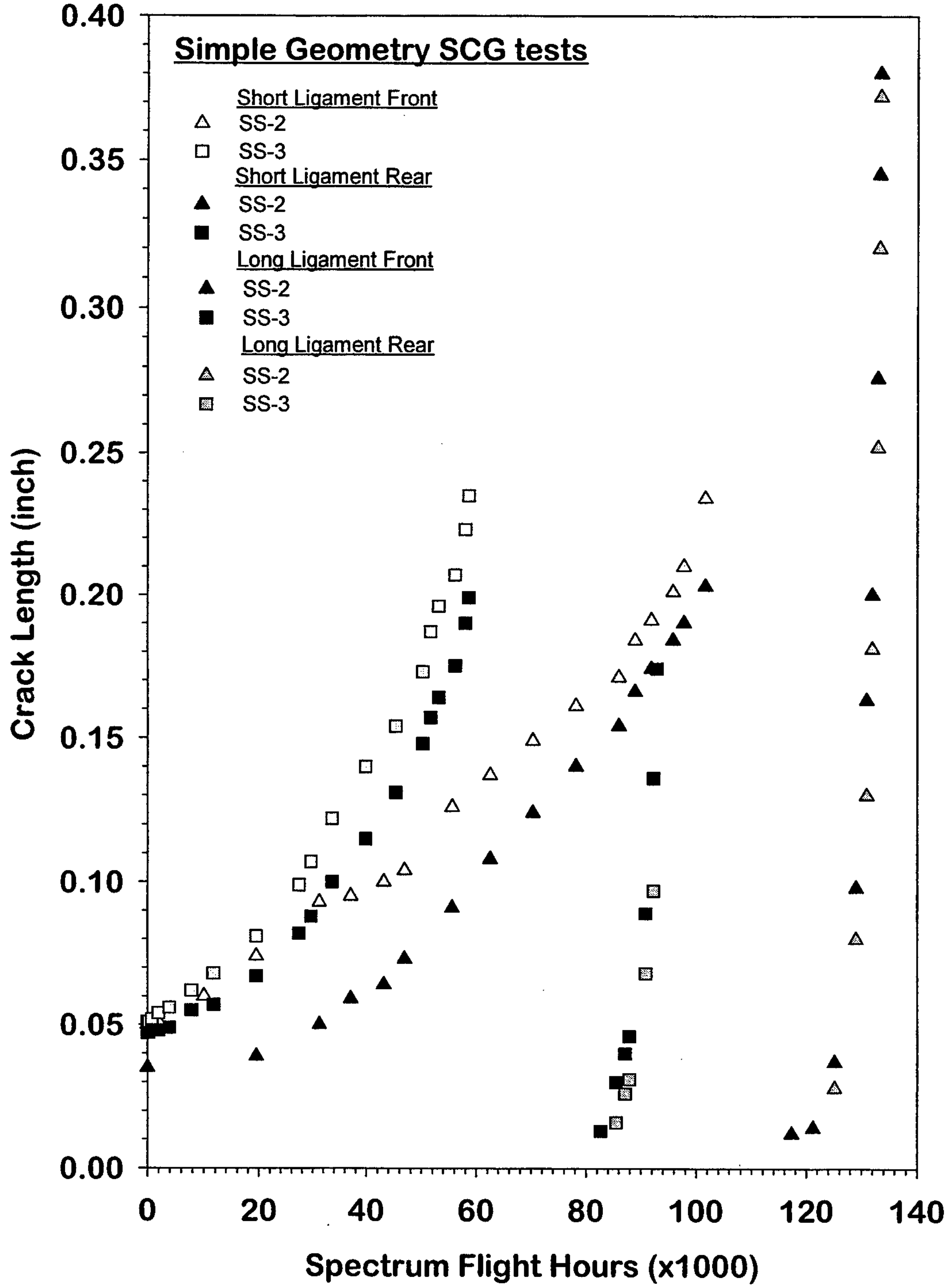


Figure F5.3 Summary of All SCG Tests Performed on the Simple Coupon Geometry

SUMMARY OF SPECTRUM PARAMETERS

Cycles per 550 SFH	Load levels (lbs) Minimum	Load levels (lbs) Maximum	Comments
14076	-1406	1451	offset hole

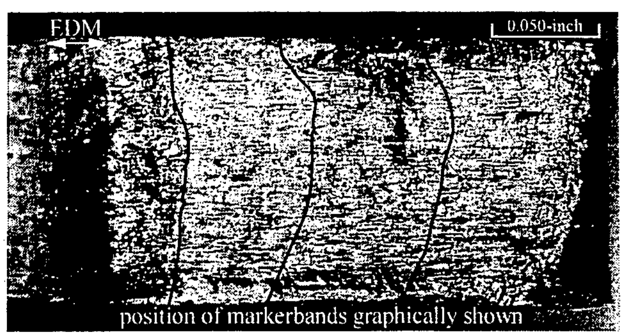
FRACTURE SURFACES

MILESTONES

Total Life = 133.5 kSFH

ligament failed at 101.6 kSFH
reinitiation at 117.3 kSFH

Test = SS-2

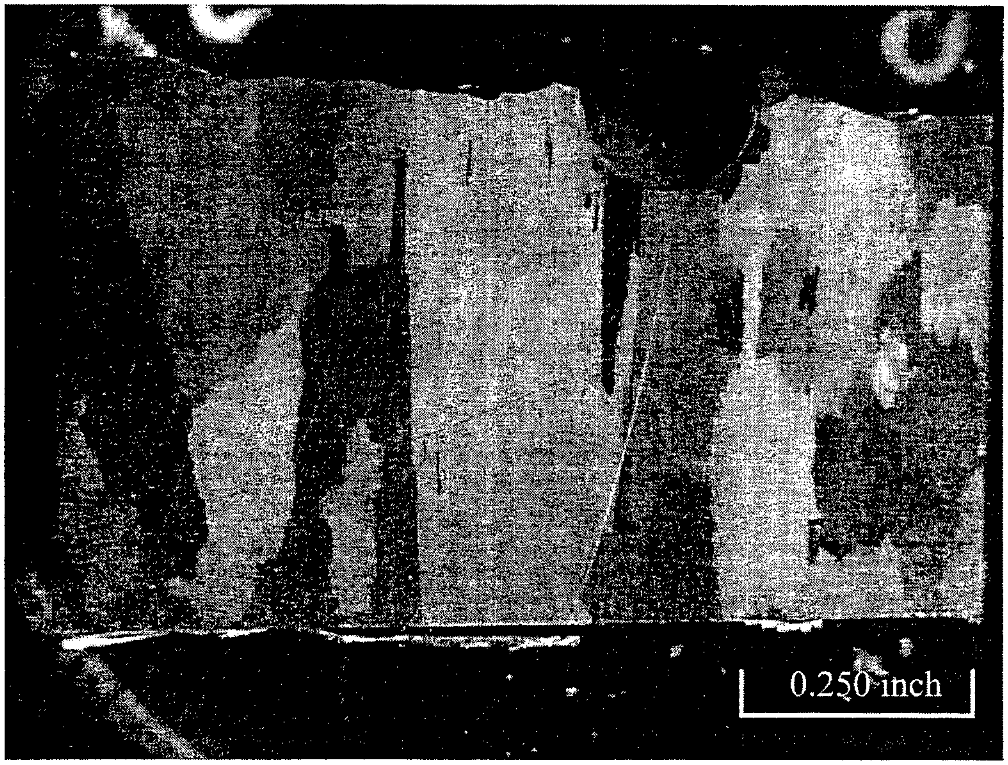


Total Life = 92.9 kSFH

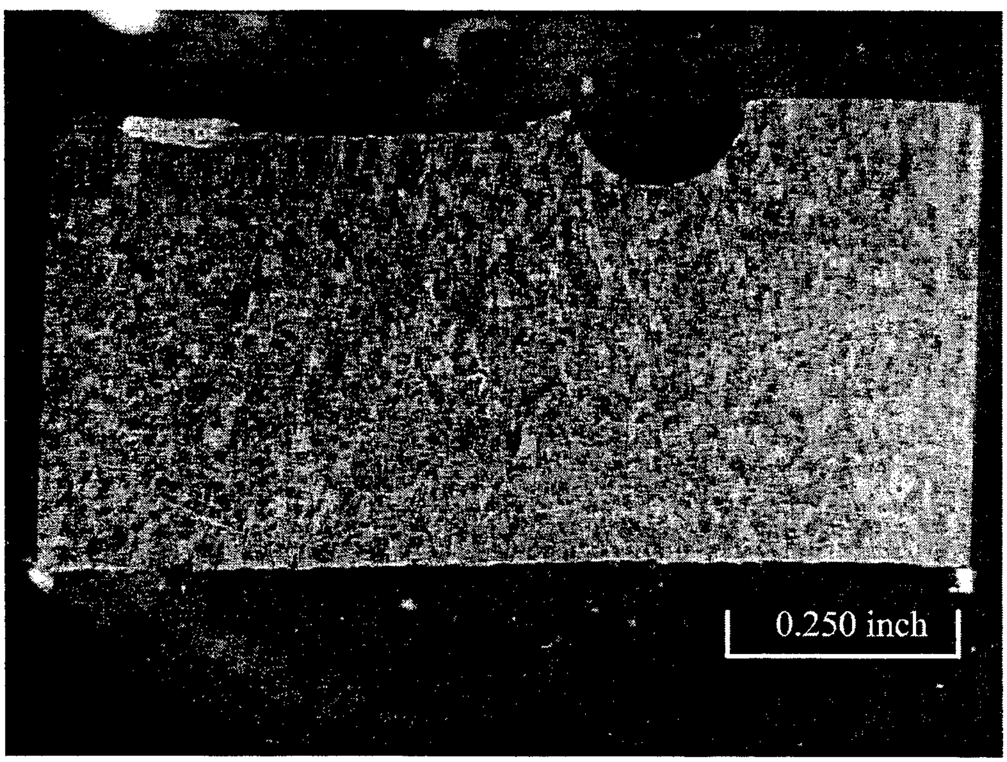
ligament failed at 58.6 kSFH
reinitiation at 82.6 kSFH

Test = SS-3

Figure F5.4 Summary of Spectrum Crack Growth Testing for the Simple Geometry Coupon

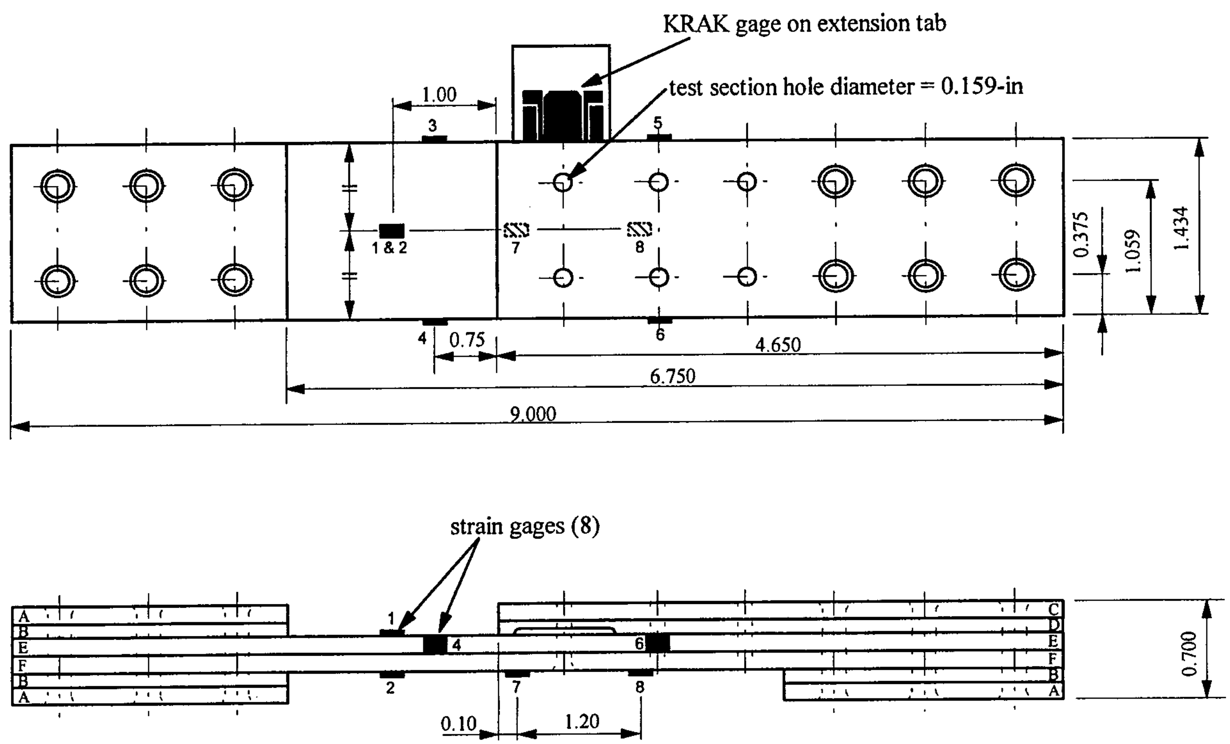


(a)



(b)

Figure F5.5 Micrographs of the Simple Geometry Coupons Highlighting the Different Grain Structures (a) Test SS-2 and (b) Test SS-3

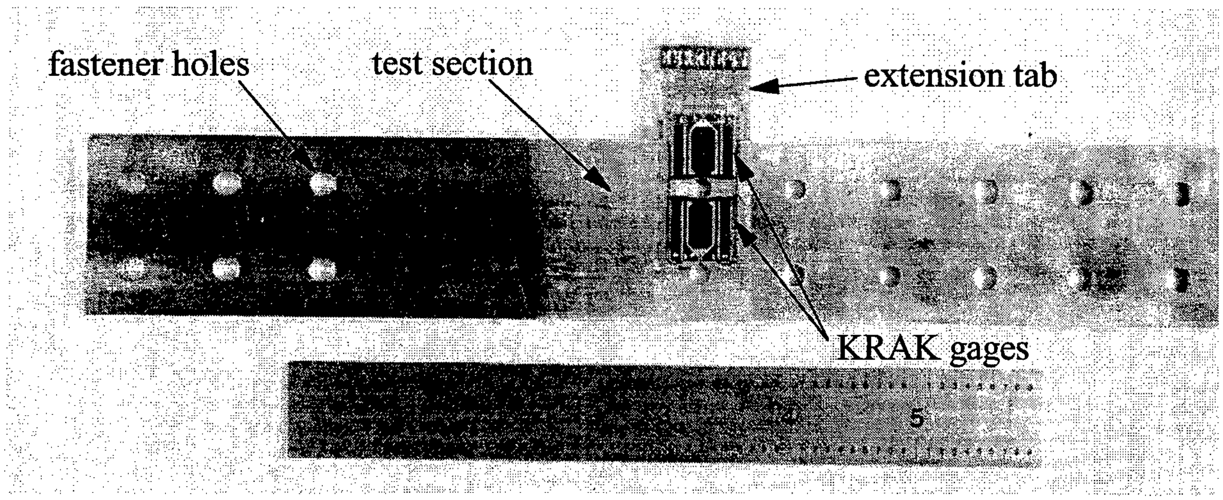


Specimen sub-parts (number required per assembly)

A. loading tabs (0.125-in thick)	3 off
B. loading tabs (0.100-in thick)	3 off
C. titanium strap (0.125-in thick)	1 off
D. titanium strap (0.100-in thick)	1 off
E. test section - spar angle (0.125-in thick)	1 off
F. spar lower cap (0.125-in thick)	1 off

	Drawn: F. J. McMaster				Southwest Research Institute San Antonio, Texas	
	Date: 2 February 1998					
Matl: various	Tolerances (inches) Basic Dimension	Decimals 2 place	Decimals 3 place	Fractions	Title SCG Coupon Geometry - Layout	
Finish: 32 rms	under 6	±0.005	±0.003	±1/32	Drawing Number 06-8250-SCG_all	Scale *** none ***
	6-24 incl	±0.010	±0.005	±1/16		
Qty Reqd: 4 assys	over 24	±0.025	±0.015	±1/6	Filename c:\fraser\swri\projects\fairchd\SCGspec.prz	Sheet 1 of 1
	angles	±0° 30'		±1° 0'		

Figure F5.6 Design for the Complex Geometry Coupon for Spectrum Crack Growth Studies



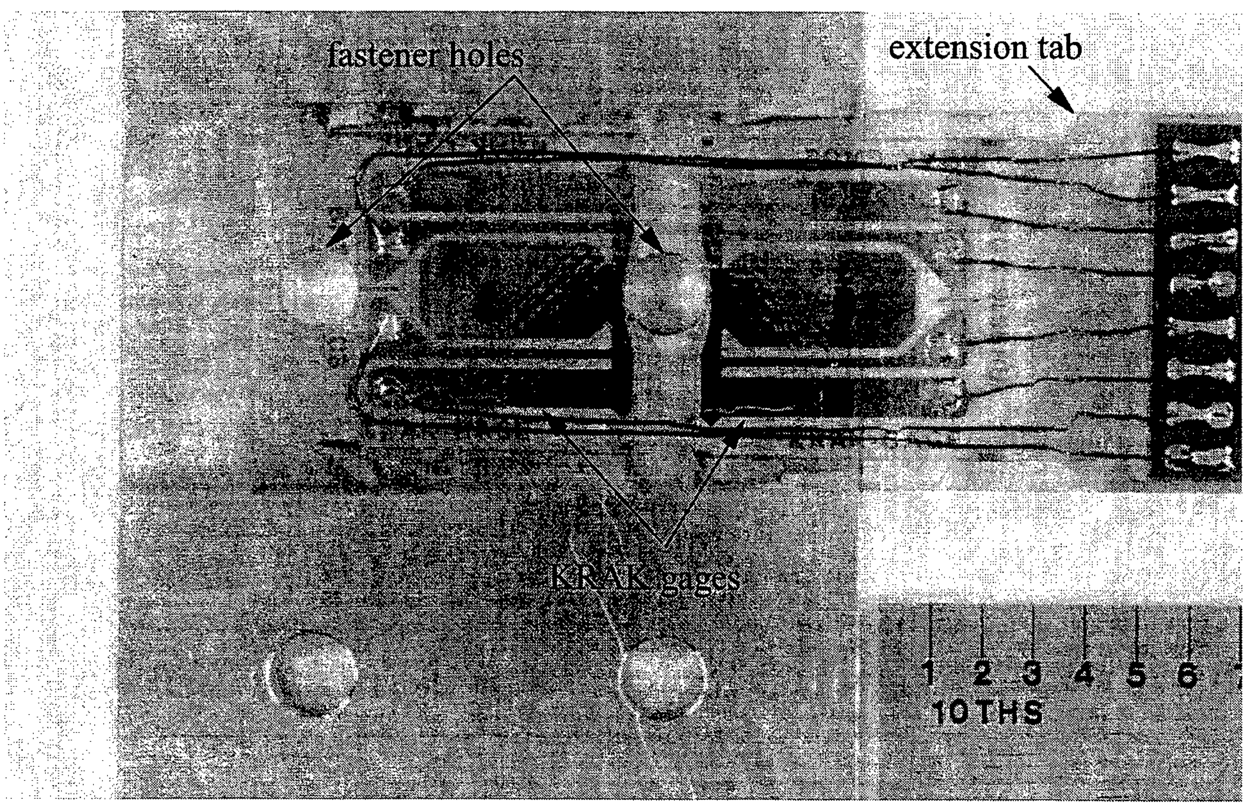


Figure F5.7 KRAK Gage Details for the Complex Geometry Coupons

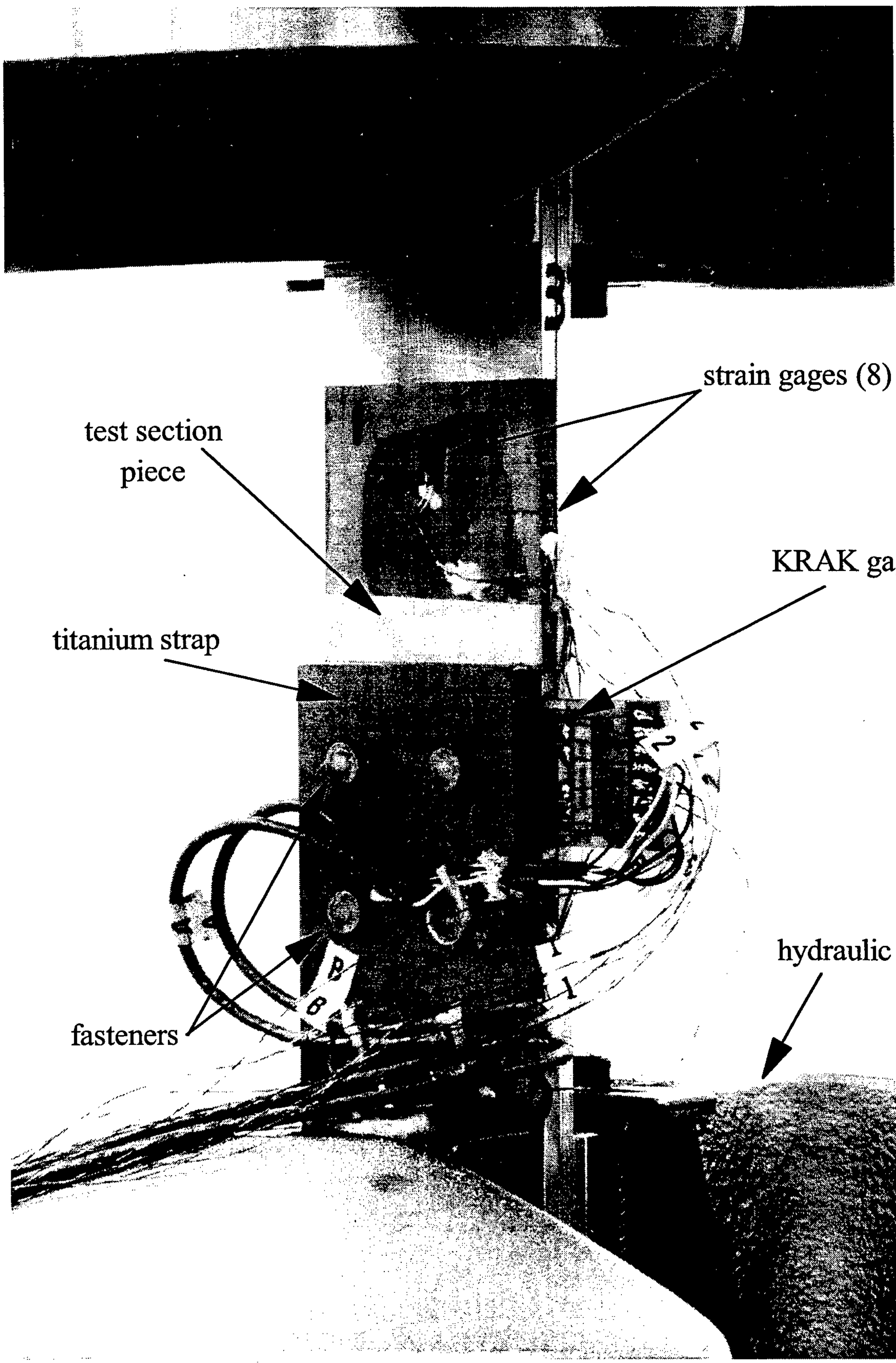


Figure F5.8 Representative Test Setup for the Complex Geometry Coupon

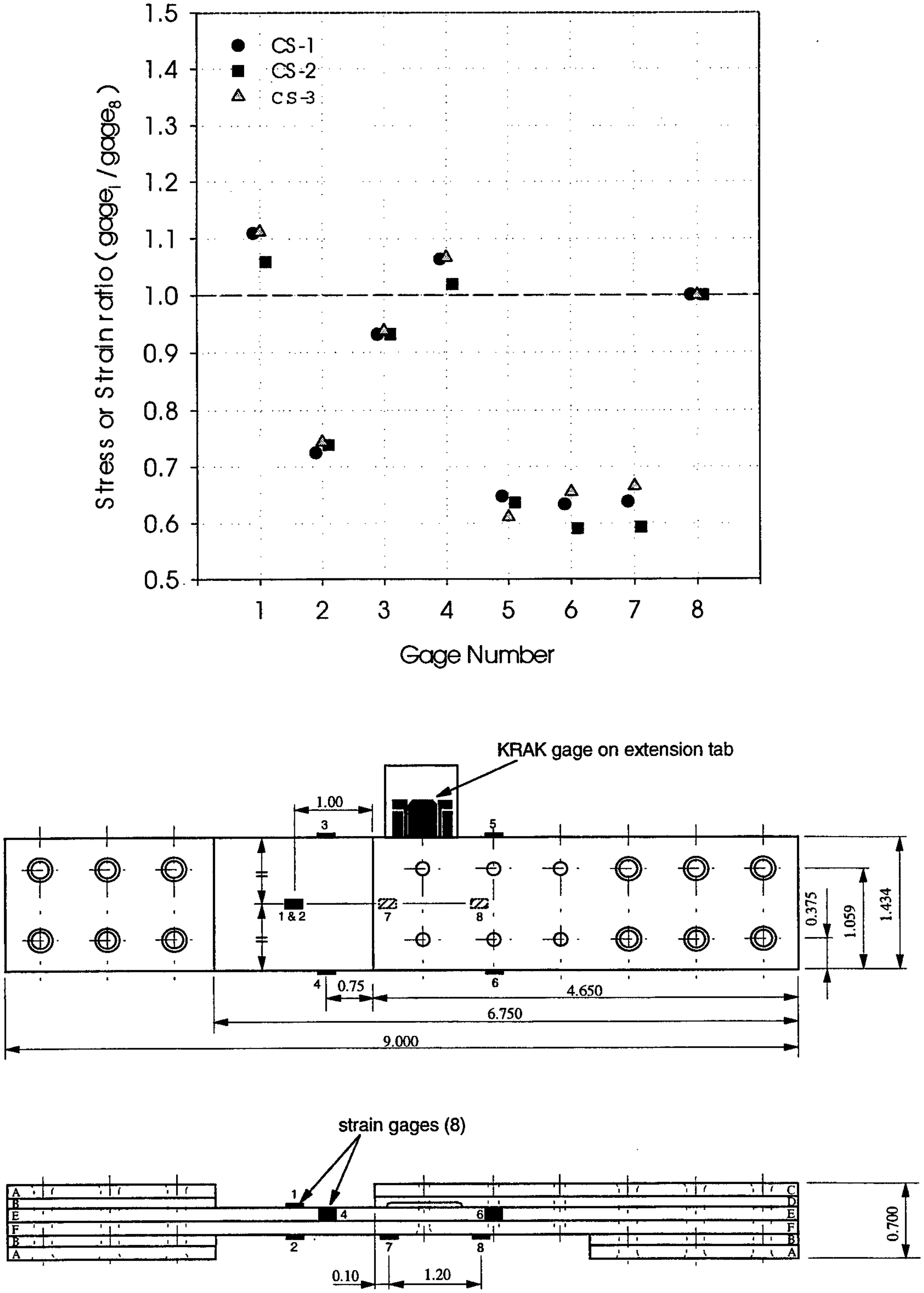


Figure F5.9 Comparison of Initial Strain Gage Readings, Normalized with Respect to Strain Gage 8

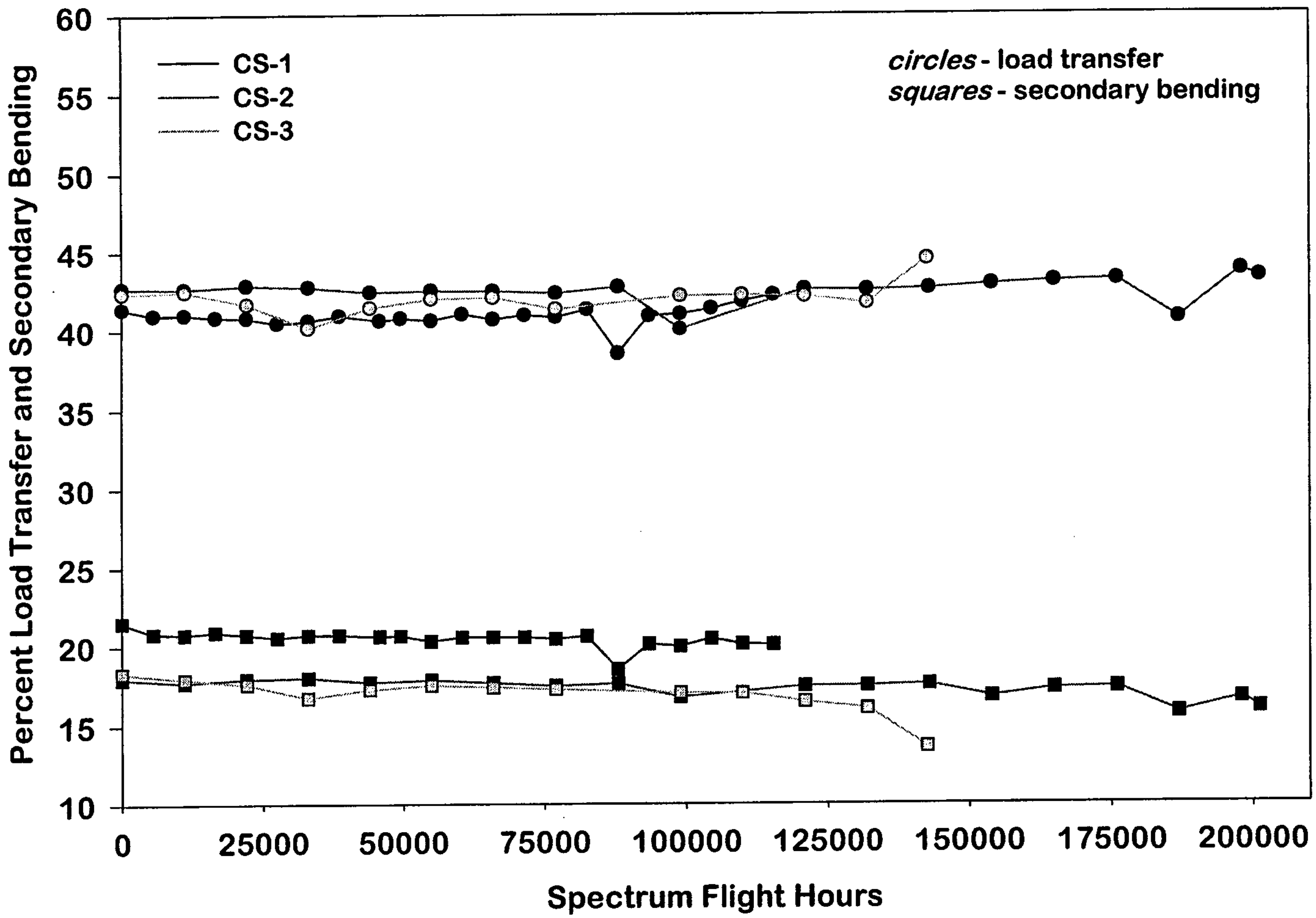


Figure F5.10 Percent Load Transfer and Secondary Bending for All Three Complex Geometry Tests

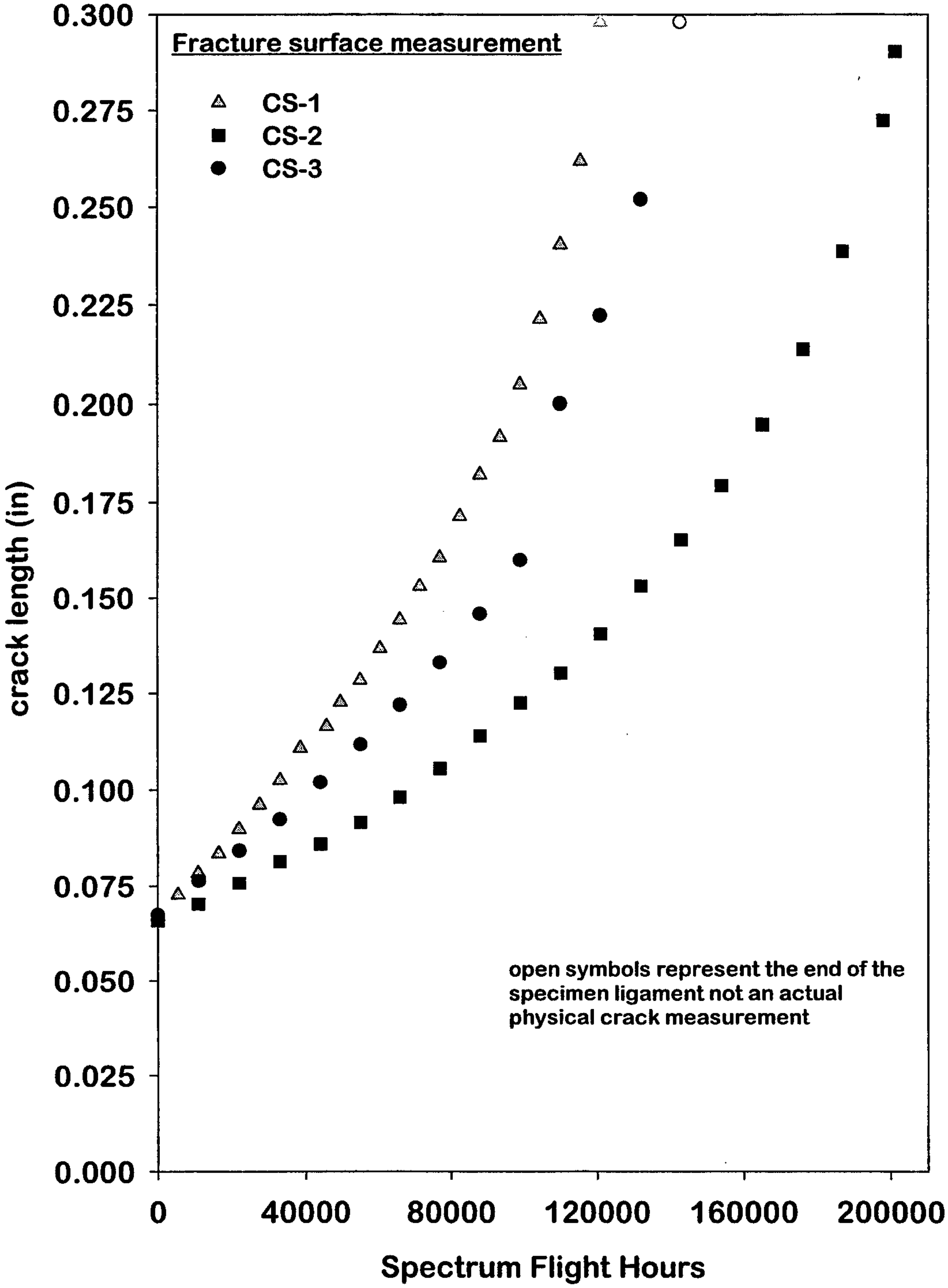


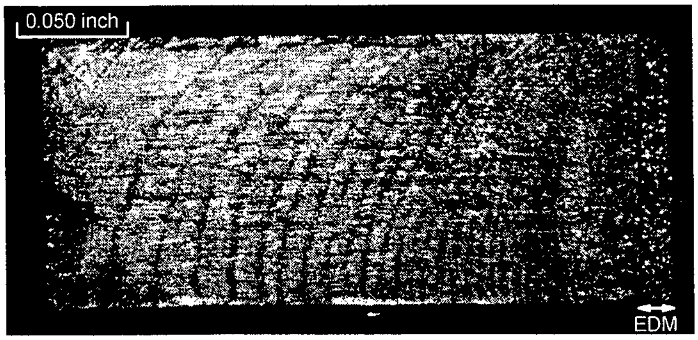
Figure F5.11 Summary of All SCG Tests Performed on the Complex Coupon Geometry

SUMMARY OF SPECTRUM PARAMETERS

Cycles per 550 SFH	Load levels (lbs) Minimum	Load levels (lbs) Maximum	Comments
14076	-4380	4520	offset hole (built-up joint)

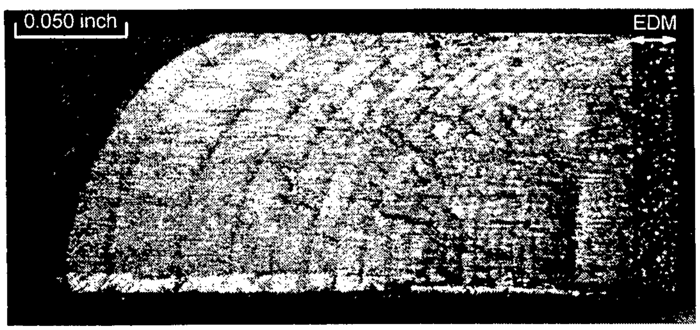
FRACTURE SURFACES

Test = CS-3
MILESTONES



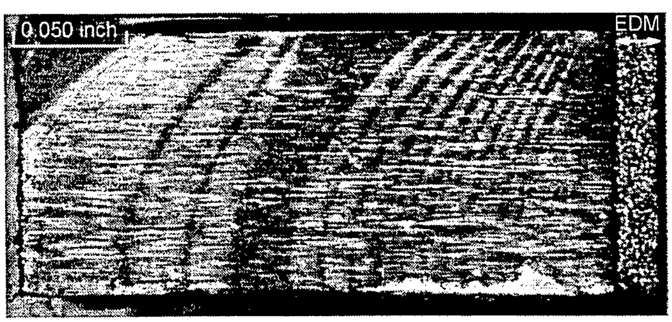
Test terminated = 121.0 kSFH

Test = CS-1



Test terminated = 201.2 kSFH

Test = CS-2



Test terminated = 142.7 kSFH

Figure F5.12 Summary of Spectrum Crack Growth Testing for the Simple Geometry Coupon

F6.0 ANALYSIS OF COUPON TESTS

Crack growth analyses of the simple and complex coupon spectrum tests were performed using NASGRO to determine if FCL W1 exhibited any effects of load interaction (retardation) and to assess the general validity of the NASGRO crack growth analysis model (Figure 6-1) used for the DTA of this location. This section presents the results of these analyses and compares them to the data obtained in the coupon tests. For reference, Appendix G3 provides listings of the batch data files and the spectrum files used in the NASGRO analyses.

F6.1 CRACK GROWTH RELATIONSHIP

The crack growth equation used in the NASGRO software [F3] is:

$$\frac{da}{dN} = \frac{C\,(1-f)^n\,\Delta K^n\left(1-\frac{\Delta K_{th}}{\Delta K}\right)^p}{(1-R)^n\left(1-\frac{\Delta K}{(1-K_c)}\right)^q} \qquad (6)$$

where N is the number of applied fatigue cycles, a is the crack length, R is the stress ratio, ΔK is the stress intensity factor range, and C, n, p, and q are parameters obtained from the curve fit to the empirical data, see Figure F3.9. The threshold intensity factor range, ΔK_{th} is approximated in NASGRO as a function of the threshold intensity factor range at $R = 0$, defined as ΔK_0. K_c is the thickness dependent fracture toughness of the material. The function f allows for the use of a crack closure model. Using this NASGRO crack growth equation, analytical comparisons were made to the coupon spectrum crack growth data and demonstrated that very good predictions were possible without the use of a retardation or closure model.

Based on the fatigue crack growth data generated in this program (Section F3.4) and the data contained in the NASGRO material properties database, the following parameters were used in the crack growth analyses of the 2014-T6511 aluminum extrusion coupon material:

C = 2.0E-09
n = 3.70
p = 0.50
q = 1.00
ΔK_0 = 2.70 ksi√in
K_c = 51.8 ksi√in

F6.2 SIMPLE COUPON ANALYSIS RESULTS

The results of the simple coupon crack growth analysis are plotted against the measured crack growth data for coupon SS-3 in Figure F6.2 demonstrating excellent agreement between analysis and test. This good level of agreement was obtained without using a retardation model and without using the closure model contained in NASGRO. Therefore, it can be concluded that load

test results obtained from coupon SS-2 were deemed anomalous due to the microstructural differences discussed in Section F5.2.3 and were not used for comparison.

F6.3 COMPLEX COUPON ANALYSIS RESULTS

The results of the complex coupon crack growth analysis are plotted against the measured crack growth data from coupons CS-1, 2 and 3 in Figure F6.3. Excellent agreement is demonstrated between analysis and test for the shortest lived test results (CS-1 and CS-3) without the use of a retardation or closure model.

The analysis of the complex coupon geometry using the NASGRO TC03 model considers only in-plane tension and pin loads and does not account for the bending that actually occurred in the test specimen. Hence, this through-crack model uses a straight crack front. The curved crack fronts shown in Figure F5.12 and the strain gage measurements shown in Figure F5.9 are indicative of the amount of bending that was present in the complex coupon as a result of the shift in the neutral axis caused by the titanium straps. The crack growth test data plotted in Figure F6.3 are those measured at the point of maximum crack length (along the lower sides of the specimens in the photographs in Figure F5.12). Thus, the comparison shown in Figure F6.3 is actually a comparison between the maximum measured crack lengths and predicted (straight front) through-crack lengths. This analysis approach is conservative in terms of life since the largest crack size is used in the model representing a straight crack front.

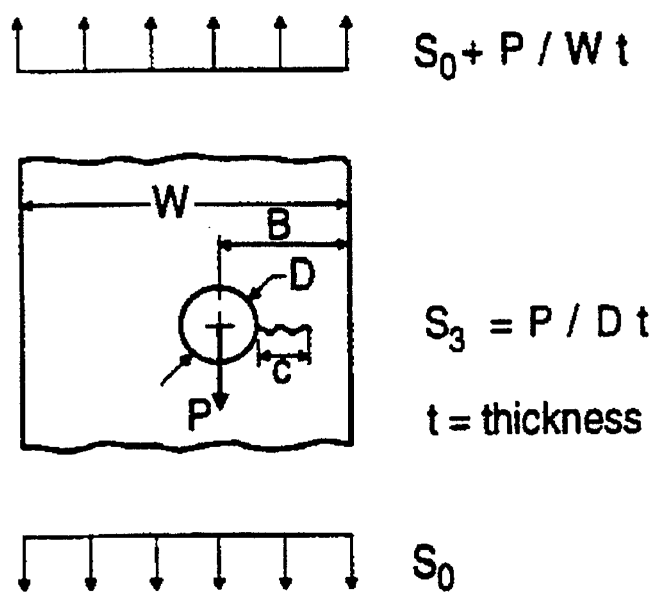


Figure F6.1 NASGRO Model TC03 for a Through-Crack From an Offset Hole in a Plate

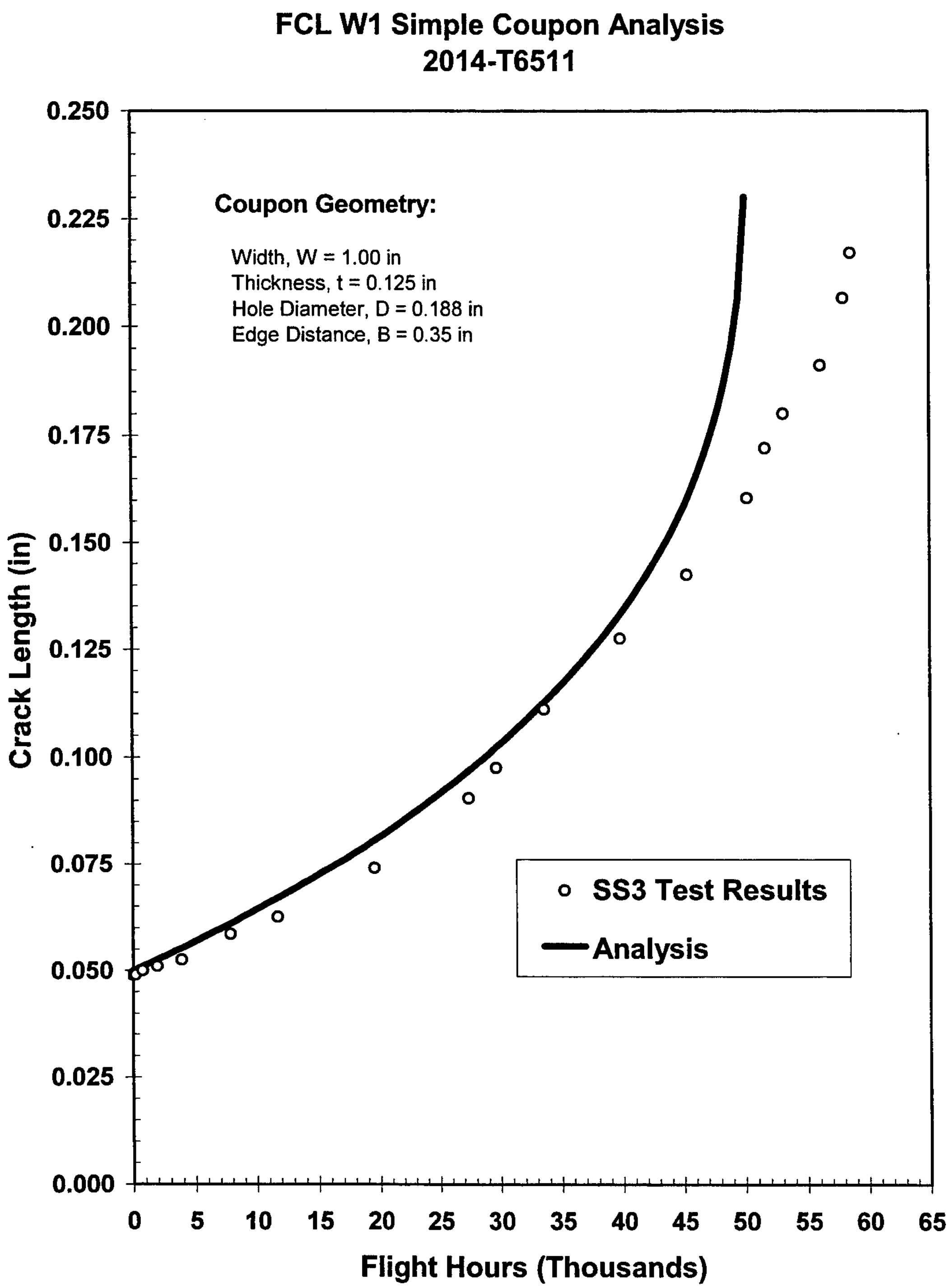


Figure F6.2 Comparison of Analysis Results with Coupon Test Results for the Simple FCL W1 Coupon Geometry

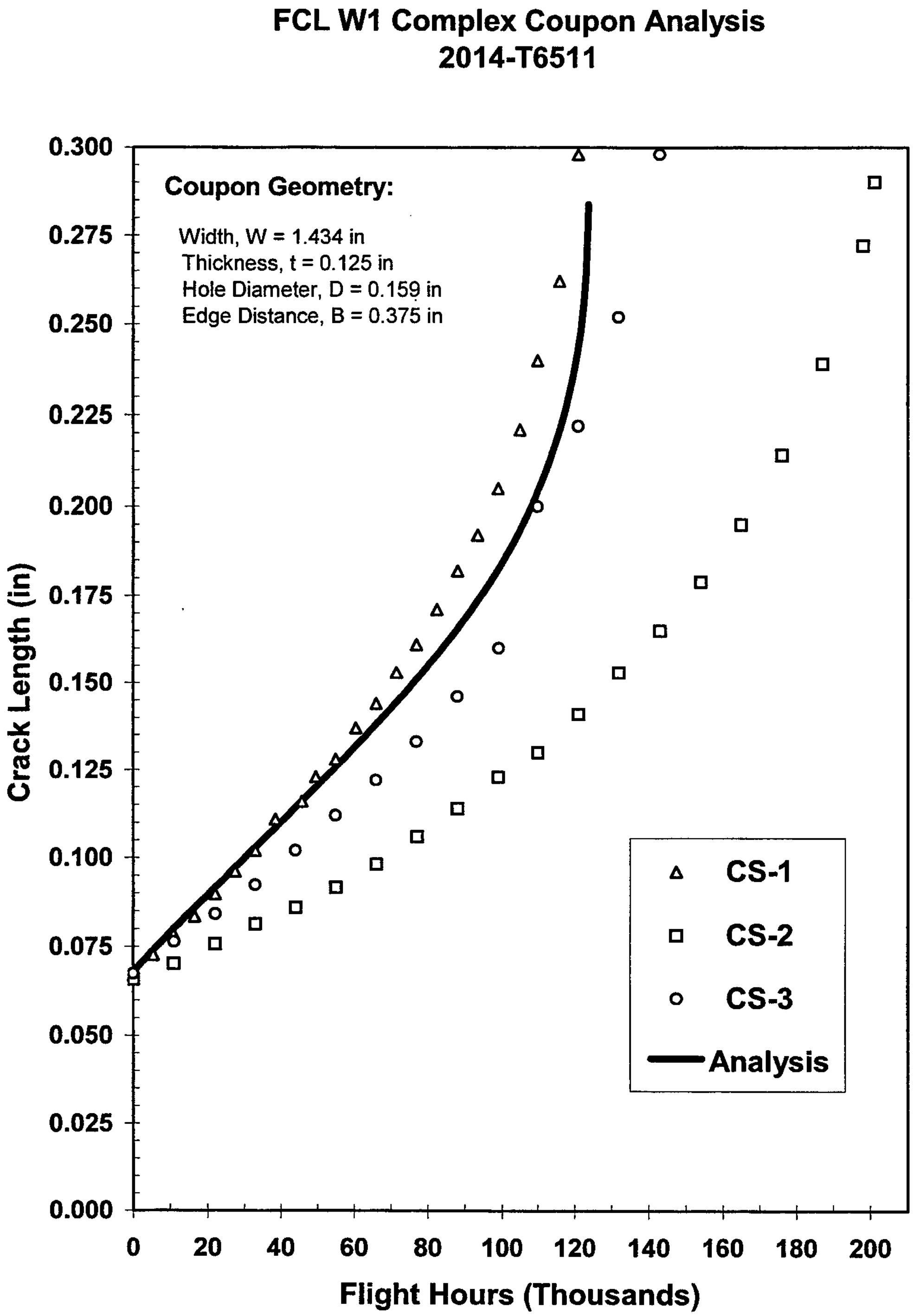


Figure F6.3 Comparison of Analysis Results With Coupon Test Results for the Complex FCL W1 Coupon Geometry

F7.0 RECOMMENDATIONS FOR DTA

Using the crack growth material properties generated in this program and the NASGRO TC03 fracture mechanics model, it was possible to accurately predict the results of both the simple and complex coupons representing FCL W1. These predictions were made without the need for invoking a retardation model indicating that load interaction effects for FCL W1 under this spectrum are not significant. These favorable results provide confidence in using the NASGRO software and these material properties in the DTA of the 2014-T6511 wing spar components on the SA226/SA227 aircraft. However, it is important to emphasize that the spectra developed for the analysis of the simple and complex coupons were specifically developed to conduct and analyze the coupon tests and should not be used for the final DTA. The original analysis spectrum should be used in the DTA.

These coupon tests and the subsequent crack growth analyses were conducted assuming the existence of a through-thickness flaw emanating from the fastener hole at FCL W1. In the DTA, additional life could be demonstrated by beginning the analyses assuming that the initial flaw was a quarter-circular corner crack having a radius of 0.05 inch. Such an analysis would be performed using NASGRO model CC02 for a corner crack growing from an offset hole in a plate. The assumption of an initial corner crack would be consistent with the recommendations made in the USAF Damage Tolerant Design Handbook [F10]. This initial flaw shape and size philosophy is also echoed in the FAA Damage Tolerance Assessment Handbook [F11].

In addition to the assumption of an initial corner crack, the DTA could also make use of the continuing damage concept where additional life beyond the failure of the short ligament is computed assuming the crack initiates on the opposite side of the hole. This analysis procedure, which is also documented in References [F10] and [F11], could be used in conjunction with a model that accounts for load redistribution into the adjacent spar structure to demonstrate additional life beyond that computed using simply NASGRO models TC03 or CC02.

F8.0 REFERENCES

F1. Dwyer, W., "Development of a Supplemental Inspection Document for SA226/SA227 Aircraft, Interim Report I," Report No. R1517, Fairchild Aircraft, May 1997.

F2. Brooks, C.L., "An Engineering Procedure to Select and Prioritize Component Evaluation under USAF Structural Integrity Requirements," McDonnell Aircraft Company, McDonnell Douglas Corporation, 1990.

F3. Forman, R.G., et al., "Fatigue Crack Growth Computer Program NASGRO," Version 2.03, JSC-22267A, NASA-JSC, May 1994.

F4. Annual Book of ASTM Standards, Section 3: Metals Test Methods and Analytical Procedures, Vol. 3.01 Metals – Mechanical Testing; Elevated and Low-Temperature Tests; Metallography, 1997.

F5. Piascik, R.S. and Newman, Jr., J.C., "An Extended Compact Tension Specimen for Fatigue Crack Growth and Fracture Testing," *International Journal of Fracture*, Vol. 76, pp. R43-R48, 1996.

F6. Military Handbook: Metallic Materials and Elements for Aerospace Vehicle Structures, MIL-HNDBK-5G, United States Department of Defense, Wright-Patterson AFB, November 1994.

F7. Donald, J.K. and Schmidt, D.W., "Computer-Controlled Stress Intensity Gradient Technique for High Rate Fatigue Crack Growth Testing," *Journal of Testing and Evaluation, JTEVA*, Vol. 8, No. 1, pp. 19-24, 1980.

F8. McKeighan, P.C. and Smith, D.J., "Determining the Potential Drop Calibration of a Fatigue Crack Growth Specimen Subjected to Limited Experimental Observations," *Journal of Testing and Evaluation, JTEVA*, Vol. 22, No. 4, pp. 291-301, 1994.

F9. Donald, J.K. and Ruschau, J., "Direct Current Potential Difference Crack Length Measurement Techniques," from *Fatigue Crack Measurement: Techniques and Applications*, K.J. Marsh, R.O. Ritchie, and R.A. Smith, Eds., EMAS, 1990.

F10. Gallagher, J.P., et al., "USAF Damage Tolerant Design Handbook," AFWAL-TR-82-3073, May 1984.

F11. Damage Tolerance Assessment Handbook, Vols. I and II, DOT-VNTSC-FAA-93-13.I, October 1993.

APPENDIX G

Testing and Analysis for DTA of Fairchild SA226 Main Wing Spar Lower Cap at WS99

FINAL REPORT
SwRI Project No. 06-8520

prepared by

Joseph W. Cardinal
Fraser J. McMaster
Peter C. McKeighan

prepared for

Fairchild Aircraft, Inc.
San Antonio, Texas

January 1999

APPROVED:

Hal Burnside, Ph.D., P.E., Director
Structural Engineering Department

APPENDIX G TESTING AND ANALYSIS FOR DTA OF FAIRCHILD SA226 MAIN WING SPAR LOWER CAP AT WS 99

APPENDIX G1
Material Characterization Properties

Data: Tensile Test Results
Fracture Toughness Results
Fatigue Crack Growth Results

Contents: Tensile Tests

- Data Sheet for each Test

Fracture Tests

- Load versus Displacement (CMOD) Response
- Analysis of Test Data

Fatigue Crack Growth Tests

- Crack Growth Plots (R-ratio)
- Crack Growth Plots (individual tests)
- Test Conditions
- Tabulated Data

Tensil Tests

7 tests:	TE-1 to –4
	TA-1 to –3

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SAN ANTONIO TX 78284
FRASER MCMASTER

P.O. # 50138

DESCR 2014-T6511 ALUMINUM EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 01

JOB NO:

SAMPLE TE-1

MECHANICAL TESTING RESULTS

THKNS: .130 WIDTH:	.505	AREA:	.0657
YIELD STRENGTH: lbs	3,984.	YIELD STRENGTH psi :	60,685
ULT STRENGTH: lbs	4,359.	TENSILE psi :	66,398
ELONG ON 2.00 IN.	.20	ELONGATION % :	10.00
		REDUCTION OF AREA % :	24.21

YIELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 10,450,000 PSI

John P. Kitson

QA INSPECTOR

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P.O. # 50138

DESCR 2014-T6511 ALUMINUM EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 02

JOB NO:

SAMPLE TE-2

MECHANICAL TESTING RESULTS

THKNS: .131 WIDTH:	.505	AREA:	.0662
YIELD STRENGTH: lbs	4,116.	YIELD STRENGTH psi :	62,218
ULT STRENGTH: lbs	4,420.	TENSILE psi :	66,813
ELONG ON 2.00 IN.	.21	ELONGATION % :	10.50
		REDUCTION OF AREA % :	27.01

'IELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 10,750,000

John Kitson

QA INSPECTOR

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DESCR 2014-T6511 ALUMINUM
EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 03 JOB NO:

SAMPLE TE-3

MECHANICAL TESTING RESULTS

THKNS: .129 WIDTH: .502		AREA:	.0648
YIELD STRENGTH: lbs	3,960.	YIELD STRENGTH psi :	61,151
ULT STRENGTH: lbs	4,266.	TENSILE psi :	65,876
ELONG ON 2.00 IN.	.22	ELONGATION % :	11.00
		REDUCTION OF AREA % :	23.05

IELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 10,730,000 PSI

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DESCR 2014-T6511 ALUMINUM
EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 04

JOB NO:

SAMPLE TE-4

MECHANICAL TESTING RESULTS

THKNS: .130 WIDTH:	.505	AREA:	.0657
YIELD STRENGTH: lbs	3,660.	YIELD STRENGTH psi :	55,750
ULT STRENGTH: lbs	4,354.	TENSILE psi :	66,321
ELONG ON 2.00 IN. :	.23	ELONGATION % :	11.50
		REDUCTION OF AREA % :	29.24

'IELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 10,930,000 PSI

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P. O. # 50138

DESCR 2014-T6511 ALUMINUM
EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 05

JOB NO:

SAMPLE TA-1

MECHANICAL TESTING RESULTS

THKNS: .127 WIDTH: .502		AREA:	.0638
YIELD STRENGTH: lbs	3,936.	YIELD STRENGTH psi :	61,737
ULT STRENGTH: lbs	4,181.	TENSILE psi :	65,580
ELONG ON 2.00 IN.	.20	ELONGATION % :	10.00
		REDUCTION OF AREA % :	20.59

YIELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 11,740,000 PSI

John Kitson
QA INSPECTOR

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EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 06

JOB NO:

SAMPLE TA-2

MECHANICAL TESTING RESULTS

THKNS: .125 WIDTH: .501		AREA:	.062
YIELD STRENGTH: lbs	3,840.	YIELD STRENGTH psi :	61,317
ULT STRENGTH: lbs	4,095.	TENSILE psi :	65,389
ELONG ON 2.00 IN.	.21	ELONGATION % :	10.50
		REDUCTION OF AREA % :	25.49

YIELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 11,250,000 PSI

QA INSPECTOR

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METALLURGICAL LABORATORIES

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P. O. # 50138

DESCR 2014-T6511 ALUMINUM
EXTRUSION

REPORT DATE: 11/17/97

LAB NO: 1110-076 / 07

JOB NO:

SAMPLE TA-3

MECHANICAL TESTING RESULTS

THKNS: .127 WIDTH:	.506	AREA:	.064:
YIELD STRENGTH: lbs	3,990.	YIELD STRENGTH psi :	62,090
ULT STRENGTH: lbs	4,171.	TENSILE psi :	64,906
ELONG ON 2.00 IN. :	.22	ELONGATION % :	11.00
		REDUCTION OF AREA % :	33.37

YIELD STRENGTH BY EXTENSOMETER 0.2% OFFSET

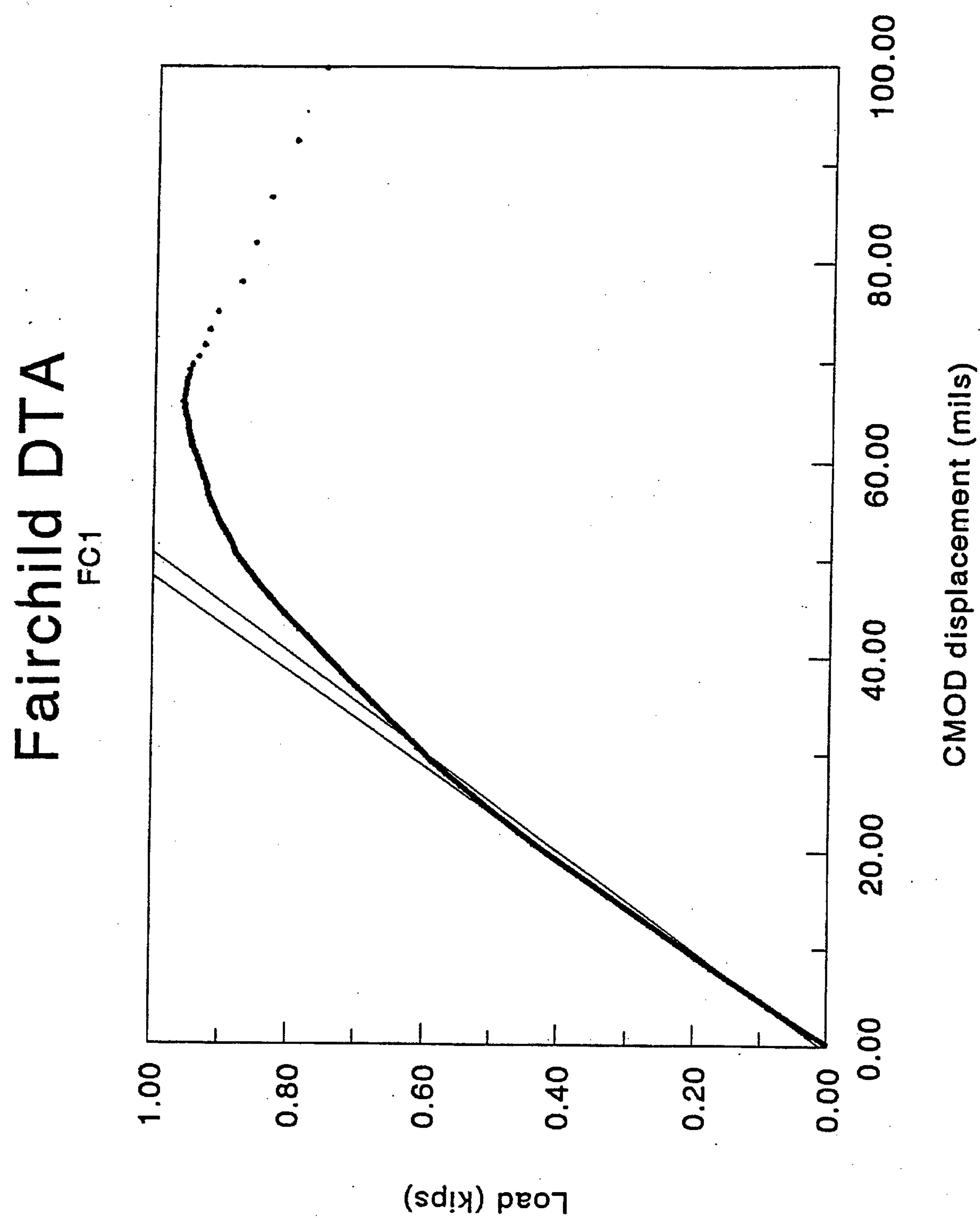
TEST METHODS: ASTM B557 ;

MODULUS OF ELASTICITY - 11,034,000 PSI

Q. A. INSPECTOR

Fracture Toughness Tests

4 tests: FC-1 to -4



Fairchild DTA
FC1
Load (kips)
0.00
0.20
0.40
0.60
0.80
1.00
CMOD displacement (mils)
0.00
20.00
40.00
60.00
80.00
100.00

***** KIc DIGITAL DATA ANALYZER *****
Version 3.0

TEST: Fairchild
PROJ: 06-8520
SPEC: fc1]

SPECIMEN/MATERIAL PROPERTIES:
Width W = 2.001 in
Thickness B = .121 in
Crack Length = 1.019 in
Youngs Modulus = 11.000 10^3 ksi
Yield Strength = 60.700 ksi

I/O PARAMETERS:
Analysis File = fc1.txt
Data/Plot File = fc1.asc
Input Data File = fc1.dat
Header = 3 rows
Data = 2 cols
LOAD: Col 1 with .200 kips/volt
CMOD: Col 2 with 10.000 mil/volt and Offset = .37 mil

=== INPUT DATA SCAN ===

Total Points = 3502
Pmax = .958 kips imax = 3479
Pmean = .494 kips
Pmin = .000 kips imin = 3

CMODmax = 99.883 mil
CMODmean = 26.279 mil
CMODmin = .273 mil

=== LINEARITY SUMMARY ===

Offset based on 20.0%-40.0% slope
Compliance = 48.624 mil/kip
Stan. Dev. = .02022

SEG	Pt Range	# PTS	% LOAD	StD	SL OFF %
1	3107 -3479	373	90.0 - 100.0	.71673	247.5
2	3020 -3380	361	87.5 - 97.5	.50598	164.7
3	2931 -3288	358	85.0 - 95.0	.32137	109.2
4	2842 -3199	358	82.5 - 92.5	.15681	74.7
5	2753 -3107	355	80.0 - 90.0	.10095	57.8
6	2663 -3020	358	77.5 - 87.5	.05437	48.9
7	2573 -2931	359	75.0 - 85.0	.02703	45.5
8	2483 -2842	360	72.5 - 82.5	.02567	45.8
9	2392 -2753	362	70.0 - 80.0	.03266	44.0
10	2307 -2663	357	67.5 - 77.5	.02993	41.6
11	2217 -2573	357	64.9 - 75.0	.02578	38.7
12	2131 -2483	353	62.5 - 72.5	.02849	38.1
13	2041 -2392	352	60.0 - 70.0	.03847	38.7
14	1952 -2307	356	57.5 - 67.5	.07515	34.1
15	1863 -2217	355	55.0 - 64.9	.08702	25.6
16	1773 -2131	359	52.5 - 62.5	.03512	17.4

17	1684	-2041	358	50.0 -	60.0	.02281	14.5
18	1593	-1952	360	47.5 -	57.5	.02499	11.9
19	1506	-1863	358	45.0 -	55.0	.02599	9.3
20	1418	-1773	356	42.5 -	52.5	.02230	6.7
21	1328	-1684	357	40.0 -	50.0	.02076	4.9
22	1240	-1593	354	37.5 -	47.5	.01556	3.5
23	1153	-1506	354	35.0 -	45.0	.01509	2.5
24	1067	-1418	352	32.5 -	42.5	.01410	1.7
25	979	-1328	350	30.0 -	40.0	.01409	1.1
26	893	-1240	348	27.5 -	37.5	.01483	.5
27	804	-1153	350	25.0 -	35.0	.01472	-.1
28	717	-1067	351	22.5 -	32.5	.01460	-.6
29	630	- 979	350	20.0 -	30.0	.01458	-1.0
30	544	- 893	350	17.5 -	27.5	.01438	-1.5
31	461	- 804	344	15.0 -	25.0	.01506	-2.2
32	379	- 717	339	12.5 -	22.5	.01728	-3.5
33	295	- 630	336	10.0 -	20.0	.01533	-4.7
34	219	- 544	326	7.5 -	17.5	.01378	-5.6
35	140	- 461	322	5.0 -	15.0	.01361	-5.8
36	71	- 379	309	2.4 -	12.5	.01732	-6.6

=== LINEAR P-CMOD ANALYSIS ===

Range = 20.0 to 40.0 (% of Pmax)
= .191 to .383 (kips)
= 630 to 1328 (points)

Compliance = 48.624 mil/kip
Intercept = -.475 mil
Coef Var = .72

Predicted Crack Length (in):

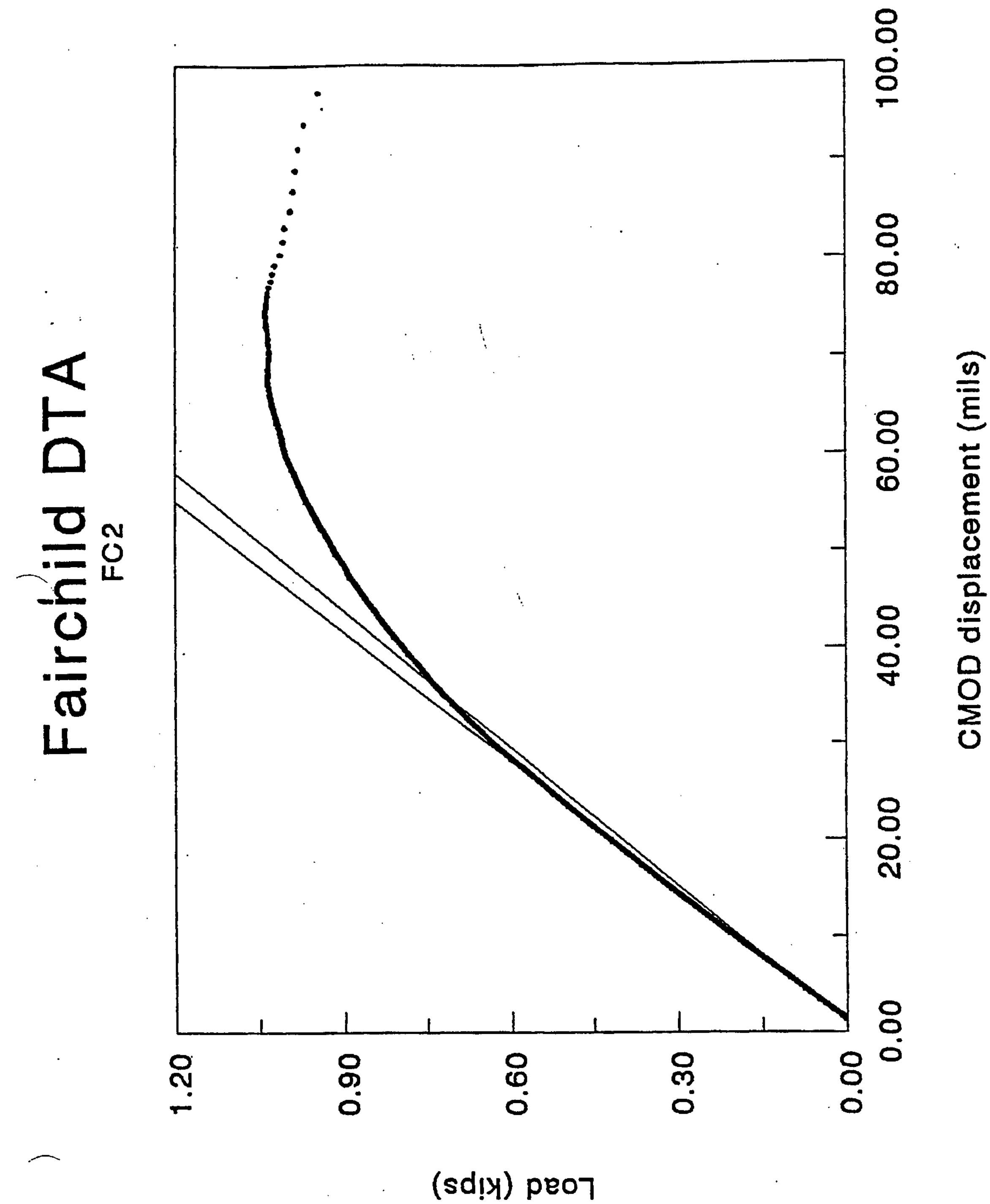
Modulus	0.9E	E	1.1E	1.2E
ACTUAL		1.019		
PREDICTED	1.028	1.074	1.113	1.148
PRED:ACT	1.009	1.054	1.092	1.127

=== TOUGHNESS ANALYSIS ===

Pmax = .958 kips
Line Fit:
slope = .02057 kips/mil
intercept = .00977 kips
P5 = .609 kips
Pq = .609 kips
Kq = 35.380 ksi-in^0.5

STATUS:

Crack Length	OK	
Thickness	INVALID (too thin)	
Pmax:Pq Ratio	INVALID Pmax/Pq=	1.572160


Fairchild DTA
FC2
Load (kips)
0.00
0.30
0.60
0.90
1.20
CMOD displacement (mils)
0.00
20.00
40.00
60.00
80.00
100.00

***** KIc DIGITAL DATA ANALYZER *****
Version 3.0

TEST: fAIRCHILD
PROJ: 06-8520
SPEC: FC2

SPECIMEN/MATERIAL PROPERTIES:
Width W = 1.998 in
Thickness B = .123 in
Crack Length = .990 in
Youngs Modulus = 11.000 10^3 ksi
Yield Strength = 60.700 ksi

I/O PARAMETERS:
Analysis File = FC2.TXT
Data/Plot File = FC2.ASC
Input Data File = FC2.DAT
Header = 3 rows
Data = 2 cols
LOAD: Col 1 with .200 kips/volt
CMOD: Col 2 with 10.000 mil/volt and Offset = .57 mil

=== INPUT DATA SCAN ===

Total Points = 3592
Pmax = 1.040 kips imax = 3572
Pmean = .496 kips
Pmin = .004 kips imin = 216

CMODmax = 100.563 mil
CMODmean = 25.924 mil
CMODmin = 1.515 mil

=== LINEARITY SUMMARY ===

Offset based on 10.0%-50.0% slope
Compliance = 45.141 mil/kip
Stan. Dev. = .06371

SEG	Pt Range	# PTS	% LOAD	StD	SL OFF %
1	3218 -3572	355	90.0 - 100.0	1.52103	276.1
2	3134 -3473	340	87.5 - 97.5	.38387	162.0
3	3050 -3384	335	85.0 - 95.0	.17129	127.1
4	2968 -3300	333	82.5 - 92.5	.10325	108.9
5	2884 -3218	335	80.0 - 90.0	.13883	93.3
6	2801 -3134	334	77.5 - 87.5	.11239	79.1
7	2717 -3050	334	75.1 - 85.0	.06662	66.2
8	2634 -2968	335	72.6 - 82.5	.07659	57.6
9	2551 -2884	334	70.1 - 80.0	.03619	51.7
10	2468 -2801	334	67.6 - 77.5	.05242	47.8
11	2384 -2717	334	65.1 - 75.1	.06766	42.6
12	2302 -2634	333	62.6 - 72.6	.05851	35.3
13	2217 -2551	335	60.1 - 70.1	.03468	30.7
14	2134 -2468	335	57.6 - 67.6	.05790	24.9
15	2052 -2384	333	55.1 - 65.1	.07628	16.7
16	1969 -2302	334	52.6 - 62.6	.05721	8.2

17	1888	-2217	330	50.2	-	60.1	.02388	4.4
18	1802	-2134	333	47.7	-	57.6	.01928	4.5
19	1720	-2052	333	45.2	-	55.1	.01523	5.6
20	1638	-1969	332	42.7	-	52.6	.01528	5.7
21	1554	-1888	335	40.2	-	50.2	.01662	4.4
22	1469	-1802	334	37.7	-	47.7	.01623	3.3
23	1387	-1720	334	35.2	-	45.2	.01415	2.4
24	1303	-1638	336	32.7	-	42.7	.01504	1.6
25	1221	-1554	334	30.2	-	40.2	.01567	.6
26	1138	-1469	332	27.7	-	37.7	.01346	-.1
27	1054	-1387	334	25.3	-	35.2	.01380	-.4
28	971	-1303	333	22.7	-	32.7	.01493	-.8
29	888	-1221	334	20.3	-	30.2	.01372	-1.1
30	804	-1138	335	17.8	-	27.7	.01359	-1.4
31	722	-1054	333	15.3	-	25.3	.01405	-1.8
32	637	- 971	335	12.8	-	22.7	.01393	-2.4
33	555	- 888	334	10.3	-	20.3	.01368	-2.6
34	472	- 804	333	7.8	-	17.8	.01432	-2.6
35	400	- 722	323	5.3	-	15.3	.01493	-2.7
36	306	- 637	332	2.8	-	12.8	.01917	-3.9

=== LINEAR P-CMOD ANALYSIS ===

```
Range = 10.0 to 50.0 (% of Pmax)
      =   .104 to   .520 (kips)
      =  543 to 1882 (points)

Compliance = 45.141 mil/kip
 Intercept =   .958 mil
  Coef Var =  1.52
```

Predicted Crack Length (in):

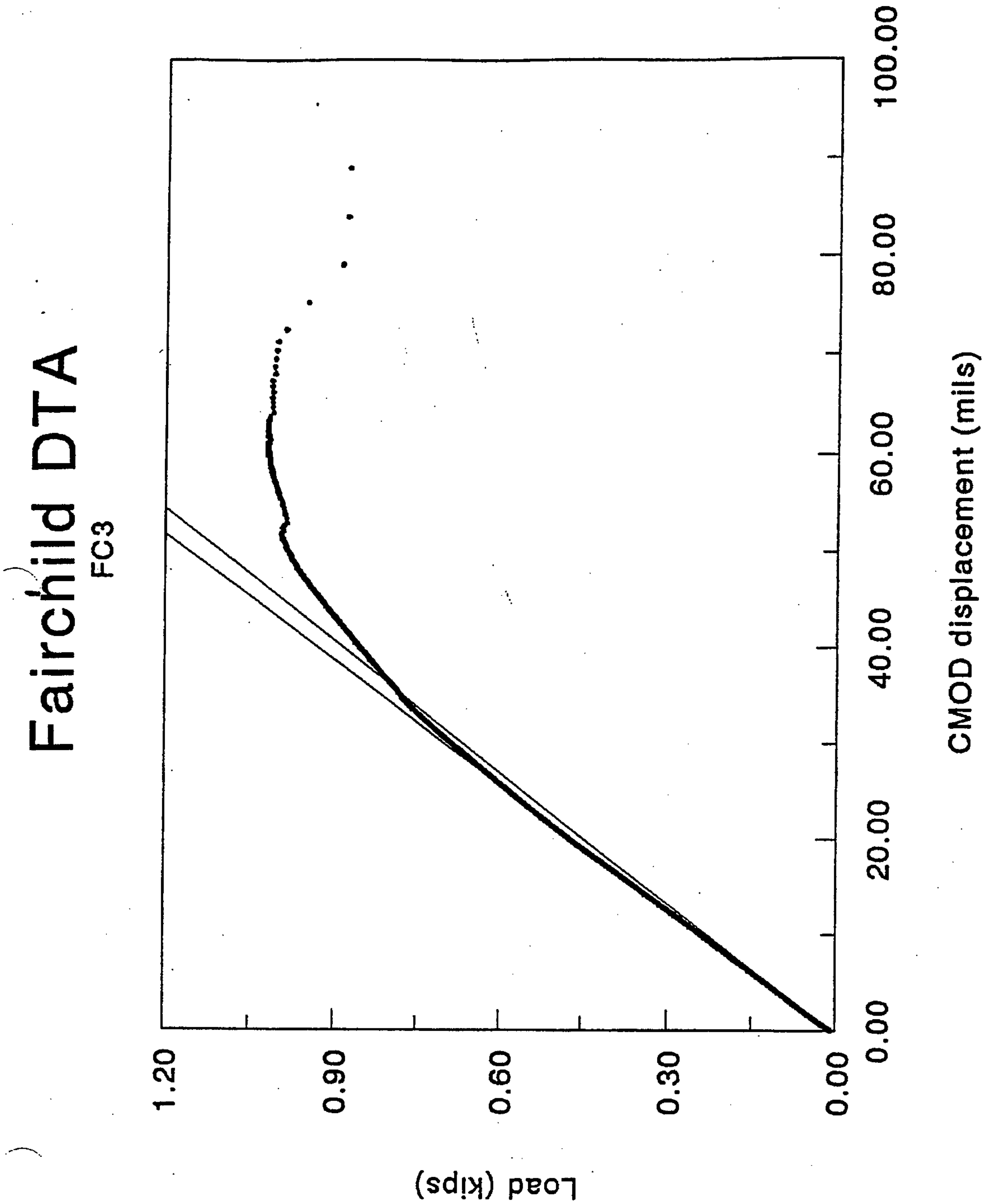
Modulus	0.9E	E	1.1E	1.2E
ACTUAL		.990		
PREDICTED	1.001	1.047	1.088	1.123
PRED:ACT	1.011	1.058	1.099	1.135

=== TOUGHNESS ANALYSIS ===

```
Pmax =  1.040 kips
Line Fit:
      slope =    .02215 kips/mil
  intercept =   -.02122 kips
 P5 =    .725 kips
 Pq =    .725 kips
 Kq =  39.742 ksi-in^0.5
```

STATUS:

Crack Length	INVALID (too short)	
Thickness	INVALID (too thin)	
Pmax:Pq Ratio	INVALID Pmax/Pq=	1.434481


Fairchild DTA
FC3
Load (kips)
0.00
0.30
0.60
0.90
1.20
0.00
20.00
40.00
60.00
80.00
100.00
CMOD displacement (mils)

```
***** KIc DIGITAL DATA ANALYZER *****
            Version 3.0

TEST: Fairchild
PROJ: 06-8520
SPEC: fc4

SPECIMEN/MATERIAL PROPERTIES:
            Width W =  1.996 in
        Thickness B =   .121 in
       Crack Length =   .978 in
     Youngs Modulus = 11.000 10^3 ksi
     Yield Strength =  60.700 ksi


I/O PARAMETERS:
       Analysis File = fc4.txt
      Data/Plot File = fc4.asc
     Input Data File = fc4.dat
         Header =  3 rows
           Data =  2 cols
          LOAD: Col  1 with   .200 kips/volt
          CMOD: Col  2 with 10.000 mil/volt and Offset =    .52 mil


=== INPUT DATA SCAN ===

  Total Points = 3734
         Pmax  =   1.055 kips    imax = 3720
         Pmean =    .489 kips
         Pmin  =    .008 kips    imin =  265

      CMODmax  = 100.517 mil
      CMODmean =  24.288 mil
      CMODmin  =    .651 mil

=== LINEARITY SUMMARY ===

  Offset based on 10.0%-50.0% slope
   Compliance =  44.994 mil/kip
   Stan. Dev. =  .06466

  SEG  Pt Range   # PTS     % LOAD        StD   SL OFF %
   1 3362 -3720    359   90.0 - 100.0  2.13790   275.3
   2 3284 -3617    334   87.5 -  97.5   .22909   144.7
   3 3194 -3530    337   85.1 -  95.0   .34981   155.7
   4 3110 -3447    338   82.6 -  92.5   .38573   151.4
   5 3025 -3362    338   80.2 -  90.0   .53876   125.1
   6 2941 -3284    344   77.7 -  87.5   .27335    74.6
   7 2858 -3194    337   75.2 -  85.1   .06848    54.9
   8 2773 -3110    338   72.7 -  82.6   .04269    47.9
   9 2690 -3025    336   70.2 -  80.2   .04108    42.6
  10 2606 -2941    336   67.8 -  77.7   .04648    37.1
  11 2523 -2858    336   65.3 -  75.2   .03866    35.0
  12 2438 -2773    336   62.8 -  72.7   .04204    32.7
  13 2353 -2690    338   60.3 -  70.2   .08245    27.2
  14 2269 -2606    338   57.8 -  67.8   .08282    17.2
  15 2186 -2523    338   55.3 -  65.3   .03813     9.5
  16 2101 -2438    338   52.8 -  62.8   .01666     7.1
```

17	2017	-2353	337	50.3 -	60.3	.01670	7.4
18	1933	-2269	337	47.9 -	57.8	.01585	7.6
19	1848	-2186	339	45.4 -	55.3	.01711	6.7
20	1767	-2101	335	42.9 -	52.8	.01592	5.3
21	1681	-2017	337	40.4 -	50.3	.01472	4.2
22	1597	-1933	337	37.9 -	47.9	.01452	3.3
23	1512	-1848	337	35.5 -	45.4	.01385	2.4
24	1428	-1767	340	33.0 -	42.9	.01450	1.5
25	1345	-1681	337	30.5 -	40.4	.01466	.8
26	1262	-1597	336	28.0 -	37.9	.01385	.3
27	1177	-1512	336	25.6 -	35.5	.01390	-.2
28	1092	-1428	337	23.0 -	33.0	.01315	-.6
29	1008	-1345	338	20.6 -	30.5	.01269	-.9
30	926	-1262	337	18.1 -	28.0	.01357	-1.3
31	842	-1177	336	15.7 -	25.6	.01448	-1.9
32	757	-1092	336	13.1 -	23.0	.01442	-2.5
33	673	-1008	336	10.7 -	20.6	.01459	-2.9
34	589	- 926	338	8.2 -	18.1	.01561	-3.5
35	507	- 842	336	5.7 -	15.7	.01517	-4.3
36	422	- 757	336	3.2 -	13.1	.01574	-5.0

=== LINEAR P-CMOD ANALYSIS ===

Range = 10.0 to 50.0 (% of Pmax)
= .105 to .527 (kips)
= 650 to 2004 (points)

Compliance = 44.994 mil/kip
Intercept = -.162 mil
Coef Var = 2.14

Predicted Crack Length (in):

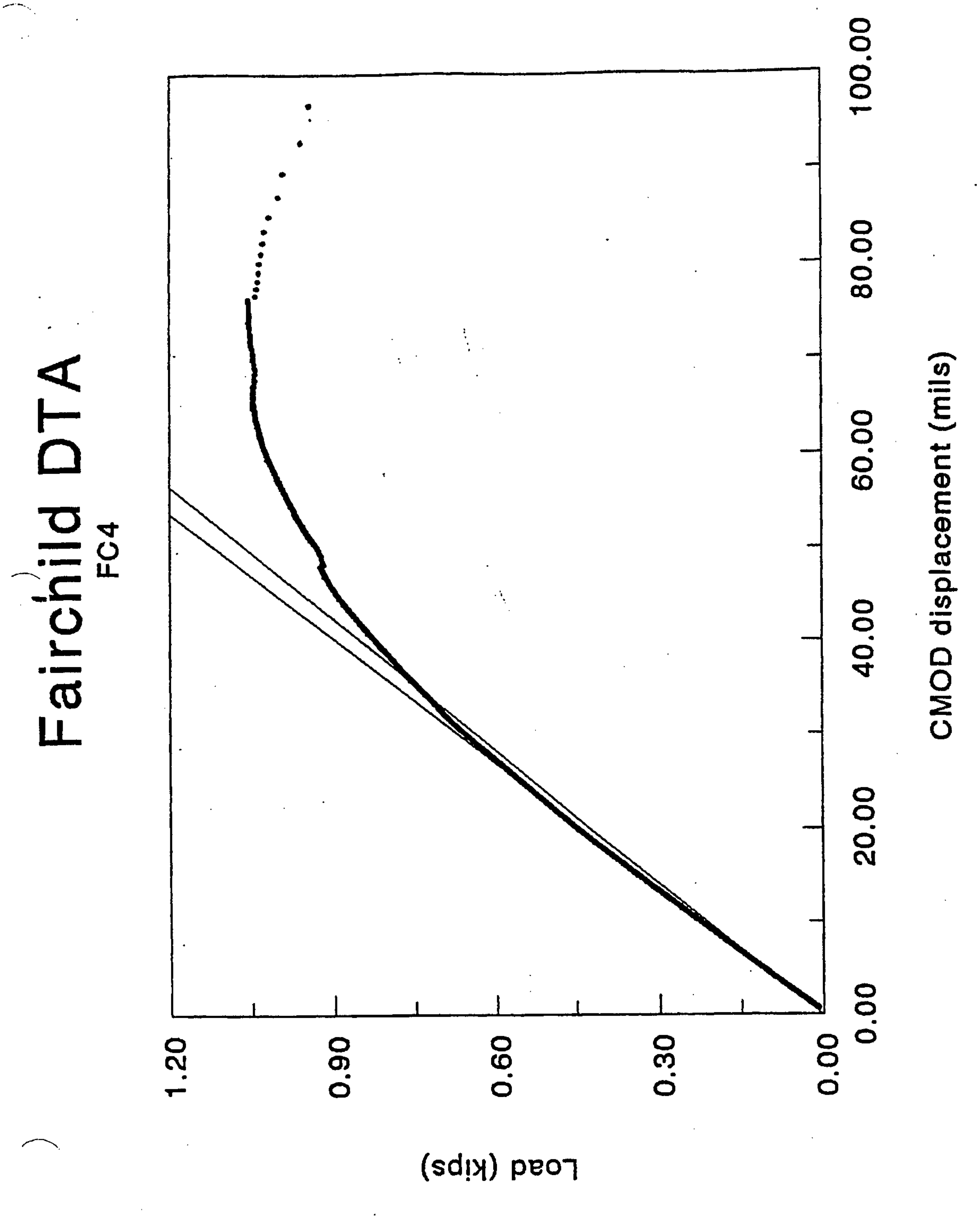
Modulus	0.9E	E	1.1E	1.2E
ACTUAL		.978		
PREDICTED	.991	1.038	1.078	1.114
PRED:ACT	1.013	1.061	1.103	1.139

=== TOUGHNESS ANALYSIS ===

Pmax = 1.055 kips
Line Fit:
slope = .02223 kips/mil
intercept = .00360 kips
P5 = .742 kips
Pq = .742 kips
Kq = 40.645 ksi-in^0.5

STATUS:

Crack Length	INVALID (too short)	
Thickness	INVALID (too thin)	
Pmax:Pq Ratio	INVALID Pmax/Pq=	1.422361



Fairchild DTA
FC4
Load (kips)
0.00
0.30
0.60
0.90
1.20
CMOD displacement (mils)
0.00
20.00
40.00
60.00
80.00
100.00

***** KIc DIGITAL DATA ANALYZER *****
Version 3.0

TEST: Fairchild
PROJ: 06-8520
SPEC: fc3

SPECIMEN/MATERIAL PROPERTIES:
Width W = 1.997 in
Thickness B = .121 in
Crack Length = .988 in
Youngs Modulus = 11.000 10^3 ksi
Yield Strength = 60.700 ksi

I/O PARAMETERS:
Analysis File = fc3.txt
Data/Plot File = fc3.asc
Input Data File = fc3.dat
Header = 3 rows
Data = 2 cols
LOAD: Col 1 with .200 kips/volt
CMOD: Col 2 with 10.000 mil/volt and Offset = -10.25 mil

=== INPUT DATA SCAN ===

Total Points = 3504
Pmax = 1.020 kips imax = 3473
Pmean = .488 kips
Pmin = .009 kips imin = 219

CMODmax = 88.929 mil
CMODmean = 22.285 mil
CMODmin = -.005 mil

=== LINEARITY SUMMARY ===

Offset based on 5.0%-55.0% slope
Compliance = 43.566 mil/kip
Stan. Dev. = .02913

SEG	Pt Range	# PTS	% LOAD	StD	SL OFF %
1	3142 -3473	332	90.1 - 100.0	1.53316	240.1
2	3059 -3402	344	87.6 - 97.5	.61249	103.3
3	2980 -3305	326	85.1 - 95.0	.06718	68.6
4	2898 -3221	324	82.6 - 92.5	.04025	62.9
5	2817 -3142	326	80.2 - 90.1	.02531	59.3
6	2735 -3059	325	77.7 - 87.6	.04159	56.8
7	2653 -2980	328	75.2 - 85.1	.04664	54.4
8	2572 -2898	327	72.7 - 82.6	.07425	48.9
9	2491 -2817	327	70.2 - 80.2	.11206	37.6
10	2411 -2735	325	67.7 - 77.7	.10495	24.7
11	2330 -2653	324	65.3 - 75.2	.03600	14.6
12	2251 -2572	322	62.8 - 72.7	.02184	11.7
13	2168 -2491	324	60.3 - 70.2	.01632	11.0
14	2087 -2411	325	57.9 - 67.7	.01627	11.0
15	2006 -2330	325	55.3 - 65.3	.01793	10.2
16	1924 -2251	328	52.9 - 62.8	.01690	8.6

17	1842	-2168	327	50.4 -	60.3	.01906	7.0
18	1762	-2087	326	47.9 -	57.9	.01894	5.2
19	1681	-2006	326	45.5 -	55.3	.01689	3.6
20	1600	-1924	325	43.0 -	52.9	.01729	1.8
21	1518	-1842	325	40.5 -	50.4	.02136	-.4
22	1436	-1762	327	38.0 -	47.9	.01788	-2.5
23	1356	-1681	326	35.5 -	45.5	.01826	-2.5
24	1275	-1600	326	33.1 -	43.0	.02105	-1.0
25	1192	-1518	327	30.6 -	40.5	.01403	.5
26	1111	-1436	326	28.1 -	38.0	.01356	.3
27	1031	-1356	326	25.6 -	35.5	.01330	.0
28	949	-1275	327	23.2 -	33.1	.01359	.0
29	870	-1192	323	20.7 -	30.6	.01351	.4
30	789	-1111	323	18.2 -	28.1	.01348	.5
31	707	-1031	325	15.7 -	25.6	.01308	.5
32	626	- 949	324	13.2 -	23.2	.01370	.2
33	544	- 870	327	10.7 -	20.7	.01364	.0
34	464	- 789	326	8.3 -	18.2	.01425	.1
35	381	- 707	327	5.7 -	15.7	.01419	.4
36	302	- 626	325	3.3 -	13.2	.01897	-.5

=== LINEAR P-CMOD ANALYSIS ===

```
Range =  5.0 to 55.0 (% of Pmax)
      =   .051 to   .561 (kips)
      =  356 to 1993 (points)

Compliance = 43.566 mil/kip
 Intercept =  -.517 mil
  Coef Var =  1.53
```

Predicted Crack Length (in):

Modulus	0.9E	E	1.1E	1.2E
ACTUAL		.988		
PREDICTED	.977	1.024	1.065	1.102
PRED:ACT	.989	1.037	1.078	1.115

=== TOUGHNESS ANALYSIS ===

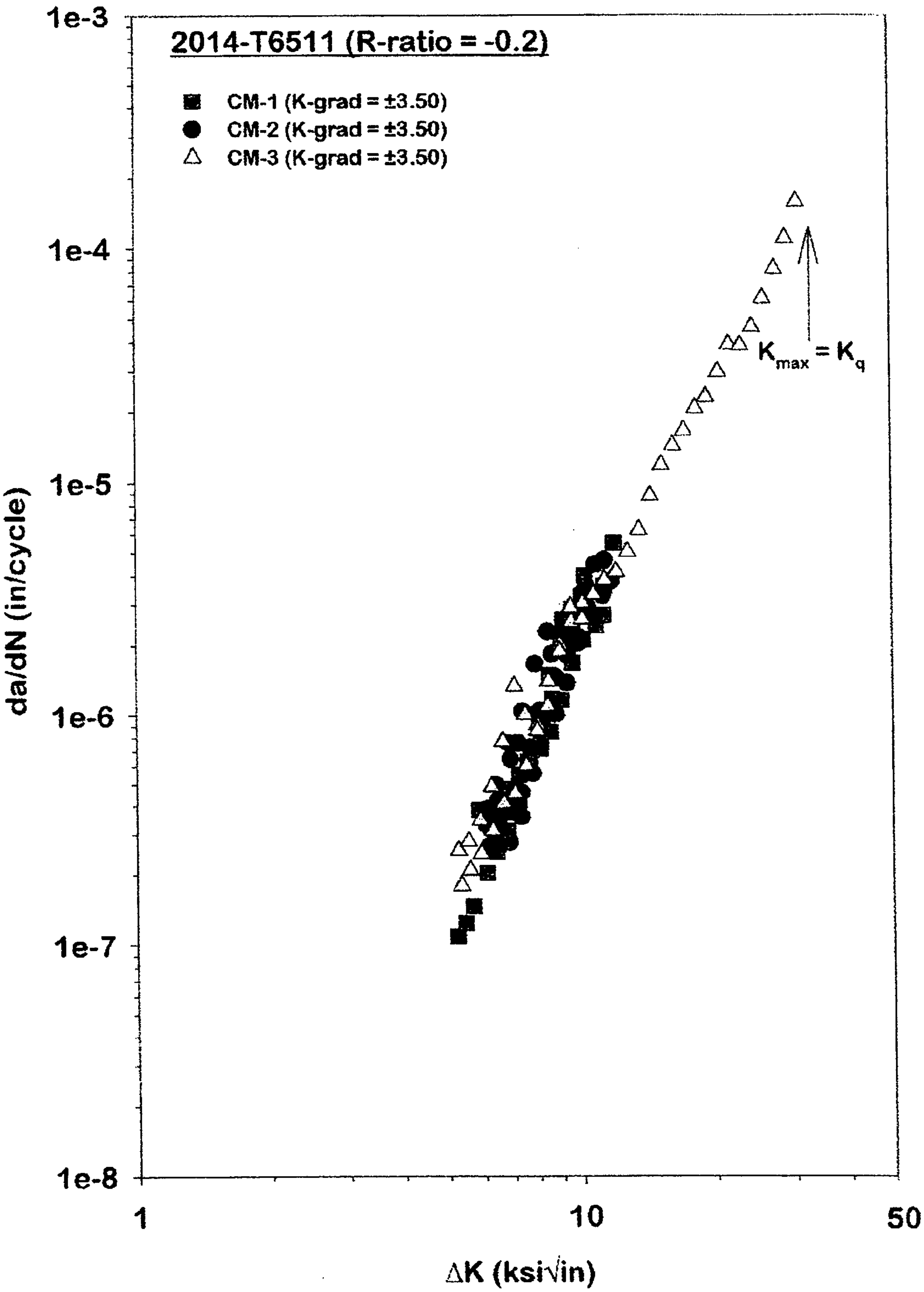
```
Pmax =  1.020 kips
Line Fit:
      slope =    .02295 kips/mil
  intercept =    .01186 kips
 P5 =   .787 kips
 Pq =   .787 kips
 Kq =  43.763 ksi-in^0.5

STATUS:

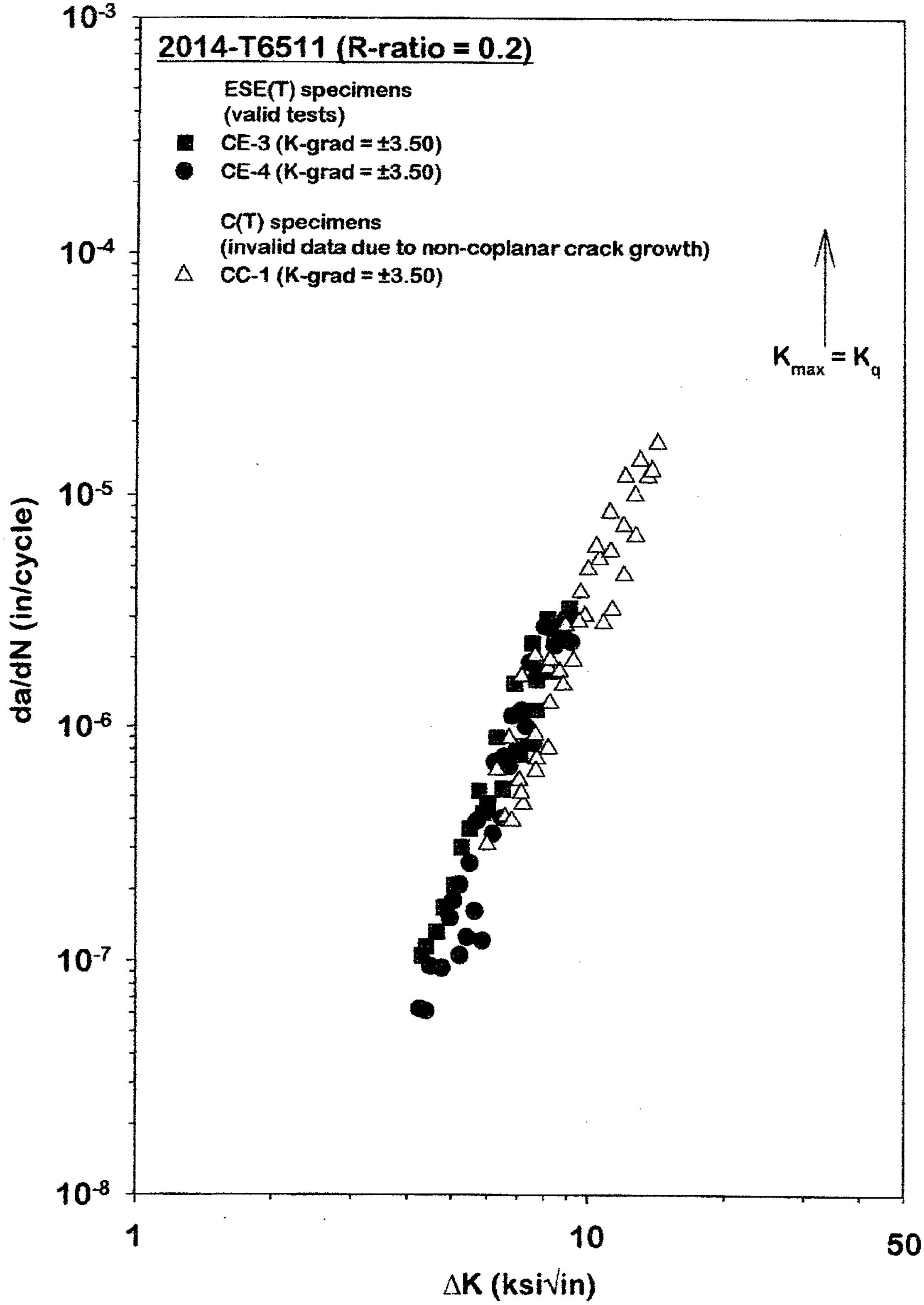
Crack Length     INVALID (too short)
Thickness        INVALID (too thin)
Pmax:Pq Ratio    INVALID  Pmax/Pq=       1.295897
```

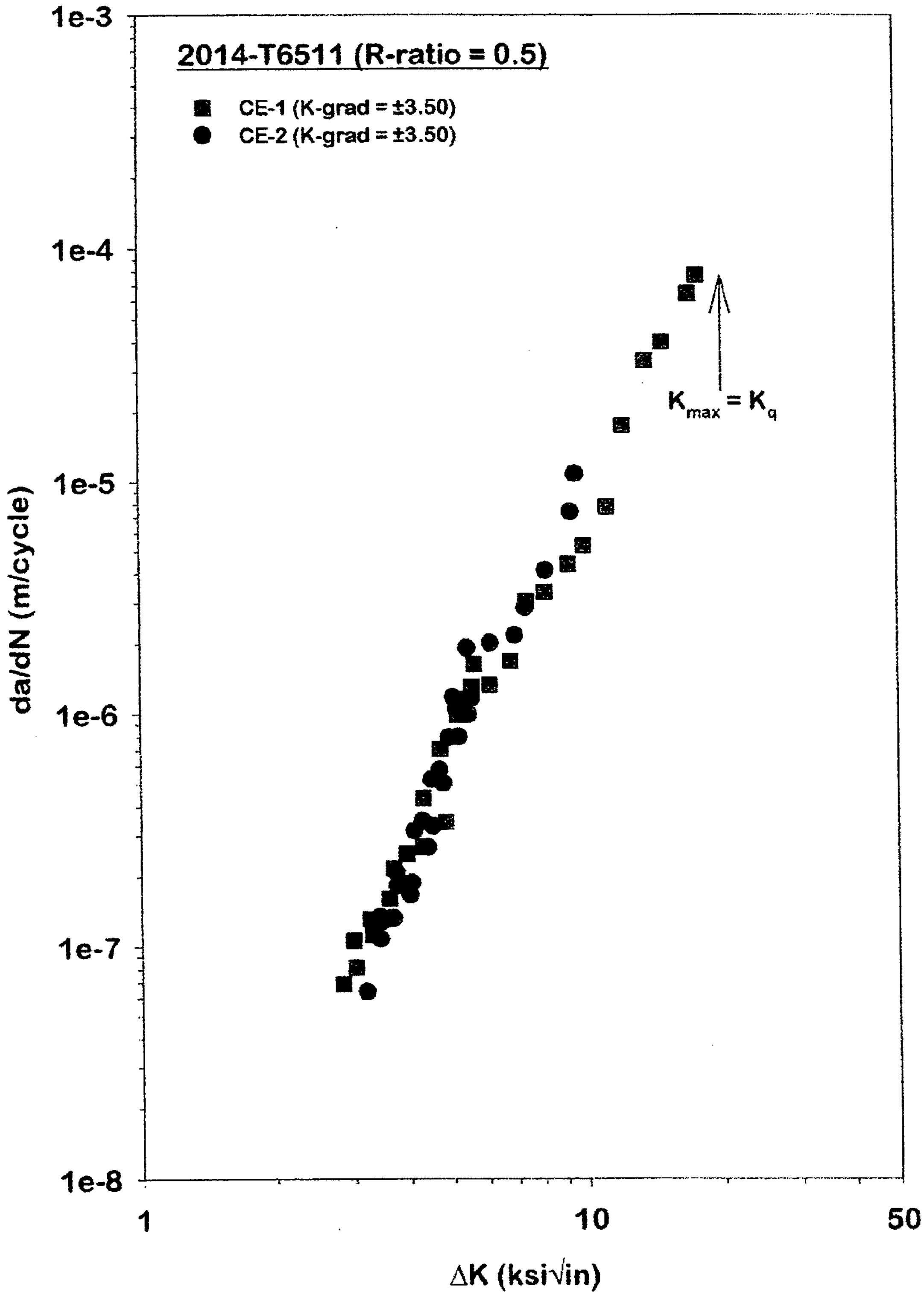
Fatigue Crack Growth Tests

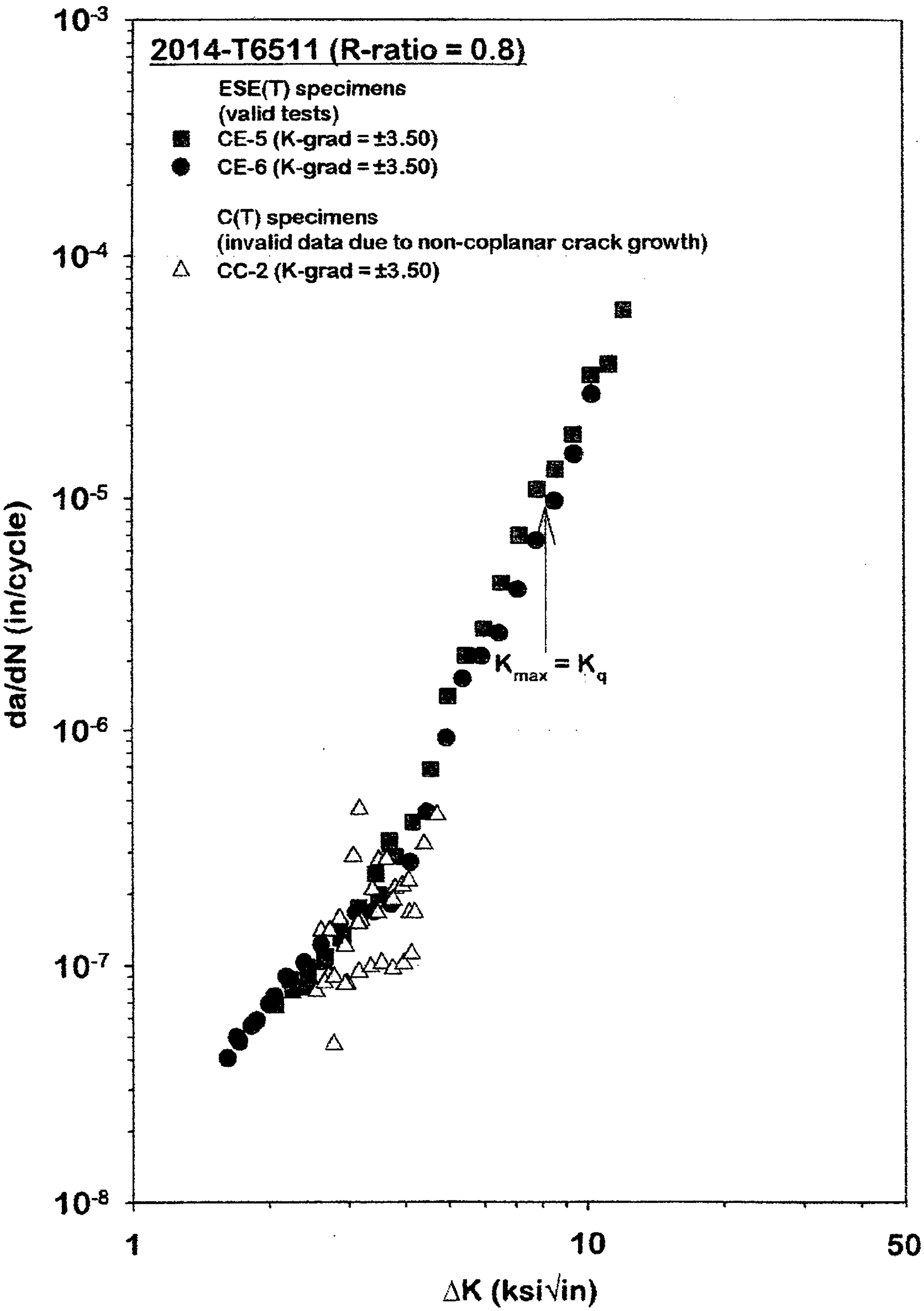
11 tests:	CC-1 to –2	C(T)
	CM-1 to –3	M(T)
	CE-1 to –6	ESE(T)



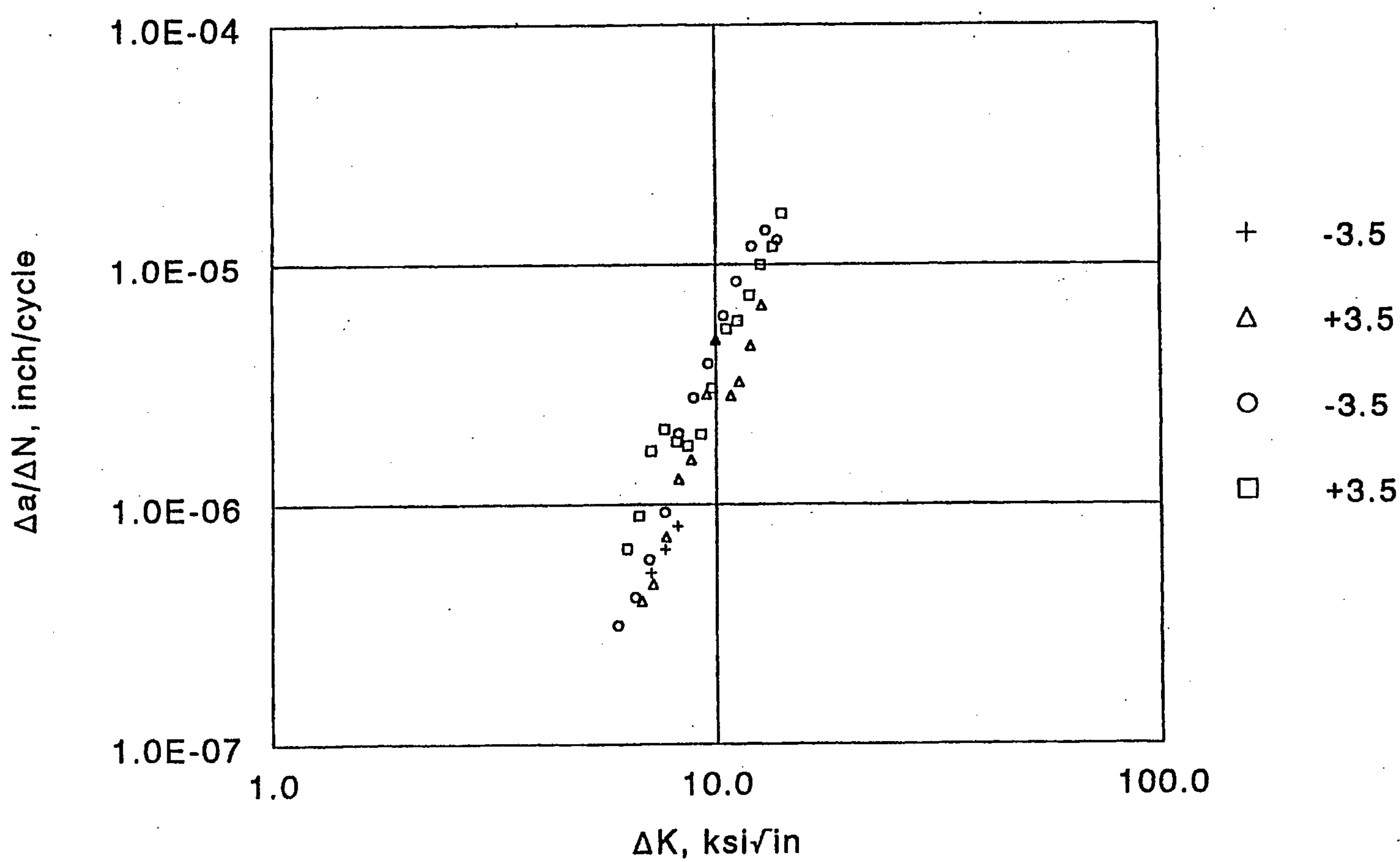
2014-T6511 (R-ratio = -0.2)
CM-1 (K-grad = ±3.50)
CM-2 (K-grad = ±3.50)
CM-3 (K-grad = ±3.50)
K
max
= K
q
da/dN (in/cycle)
1e-3
1e-4
1e-5
1e-6
1e-7
1e-8
1
10
50
ΔK (ksi√in)


2014-T6511 (R-ratio = 0.2)
ESE(T) specimens
(valid tests)
CE-3 (K-grad = ±3.50)
CE-4 (K-grad = ±3.50)
C(T) specimens
(invalid data due to non-coplanar crack growth)
CC-1 (K-grad = ±3.50)
$K_{max} = K_q$
da/dN (in/cycle)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1
10
50
ΔK (ksi√in)


2014-T6511 (R-ratio = 0.5)
CE-1 (K-grad = ±3.50)
CE-2 (K-grad = ±3.50)
$K_{max} = K_q$
da/dN (m/cycle)
1e-3
1e-4
1e-5
1e-6
1e-7
1e-8
1
10
50
ΔK (ksi√in)


2014-T6511 (R-ratio = 0.8)
ESE(T) specimens
(valid tests)
CE-5 (K-grad = ±3.50)
CE-6 (K-grad = ±3.50)
C(T) specimens
(invalid data due to non-coplanar crack growth)
CC-2 (K-grad = ±3.50)
$K_{max} = K_q$
da/dN (in/cycle)
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
1
10
50
ΔK (ksi√in)

Fairchild DTA 06-8520 CC1
2014-T65121 EXTR CT SPEC. R=0.2



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC1	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.534
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.525
Width	2.002	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	350.0	Stress ratio (R)	0.20
Final a (in)	0.584	Kmax	10.92

Test Parameters

Initial a (in)	0.584	Initial K	10.90
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
0.886000	0.272840	KRPP	1	0
4.640000	0.488940			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
38.26	0.583	0.584	0.000	0.995
127.74	0.664	0.664	0.000	0.942

Comments

Date of test: 12-12-1997

Specimen Id. CC1 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi√in
	38.3	0.5835	6				
321	54.6	0.5989	13722	0.0333	41236	8.087E-07	8.18
295	74.1	0.6168	41241	0.0356	55111	6.454E-07	7.69
268	93.6	0.6344	68833	0.0364	70670	5.158E-07	7.15
	115.2	0.6533	111911				

GROWTH RATE ANALYSIS

Specimen Id.	CC1A	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.534
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.525
Width	2.002	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	0.0	Stress ratio (R)	0.00
Final a (in)	0.000	Kmax	0.00

Test Parameters

Initial a (in)	0.664	Initial K	8.00
K-gradient	3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
0.886000	0.269210	KRPP	1	0
4.640000	0.488940			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
127.63	0.664	0.664	0.000	1.001
376.79	0.841	0.841	0.000	0.819

Comments

Date of test: 12-12-1997

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.
	127.5	0.6639	52				
240	143.0	0.6775	37121	0.0310	78742	3.932E-07	6.78
250	163.4	0.6948	78794	0.0341	73321	4.644E-07	7.19
261	183.6	0.7115	110442	0.0336	46294	7.268E-07	7.69
273	205.0	0.7285	125087	0.0329	25876	1.270E-06	8.21
286	225.9	0.7444	136318	0.0312	20455	1.526E-06	8.77
302	246.8	0.7597	145542	0.0363	12599	2.881E-06	9.49
312	276.9	0.7807	148917	0.0274	5650	4.853E-06	9.95
329	286.5	0.7871	151192	0.0202	7089	2.843E-06	10.75
340	307.8	0.8008	156006	0.0263	8089	3.254E-06	11.23
355	328.2	0.8134	159281	0.0245	5348	4.583E-06	11.93
370	348.5	0.8253	161355	0.0231	3418	6.753E-06	12.65
	368.5	0.8365	162699				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC1B	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.534
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.525
Width	2.002	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	0.0	Stress ratio (R)	0.00
Final a (in)	0.000	Kmax	0.00

Test Parameters

Initial a (in)	0.841	Initial K	18.80
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
0.886000	0.228800	KRPP	1	0
4.640000	0.491630			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
393.45	0.841	0.841	0.000	0.989
662.40	1.048	1.048	0.000	0.905

Comments

Date of test: 12-15-1997

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	393.4	0.8410	12				
387	407.2	0.8527	1013	0.0304	2397	1.267E-05	13.79
357	429.5	0.8714	2409	0.0351	2510	1.398E-05	12.97
324	449.5	0.8878	3522	0.0310	2597	1.196E-05	12.04
293	467.5	0.9024	5006	0.0321	3794	8.473E-06	11.14
268	489.4	0.9199	7316	0.0328	5372	6.097E-06	10.39
241	508.7	0.9352	10378	0.0312	8074	3.863E-06	9.60
219	529.3	0.9511	15391	0.0315	11311	2.789E-06	8.90
198	549.8	0.9667	21689	0.0307	15616	1.965E-06	8.24
180	569.9	0.9818	31007	0.0283	30616	9.249E-07	7.65
162	587.8	0.9950	52305	0.0292	49852	5.865E-07	7.05
147	609.8	1.0110	80858	0.0297	72866	4.076E-07	6.56
131	629.0	1.0247	125171	0.0301	96920	3.111E-07	5.99
	652.5	1.0412	177779				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC1C	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.534
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.525
Width	2.002	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	0.0	Stress ratio (R)	0.00
Final a (in)	0.000	Kmax	0.00

Test Parameters

Initial a (in)	1.048	Initial K	7.40
K-gradient	3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
0.886000	0.202560	KRPP	1	0
4.640000	0.488940			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
657.49	1.048	1.048	0.000	0.998
924.94	1.273	1.273	0.000	0.959

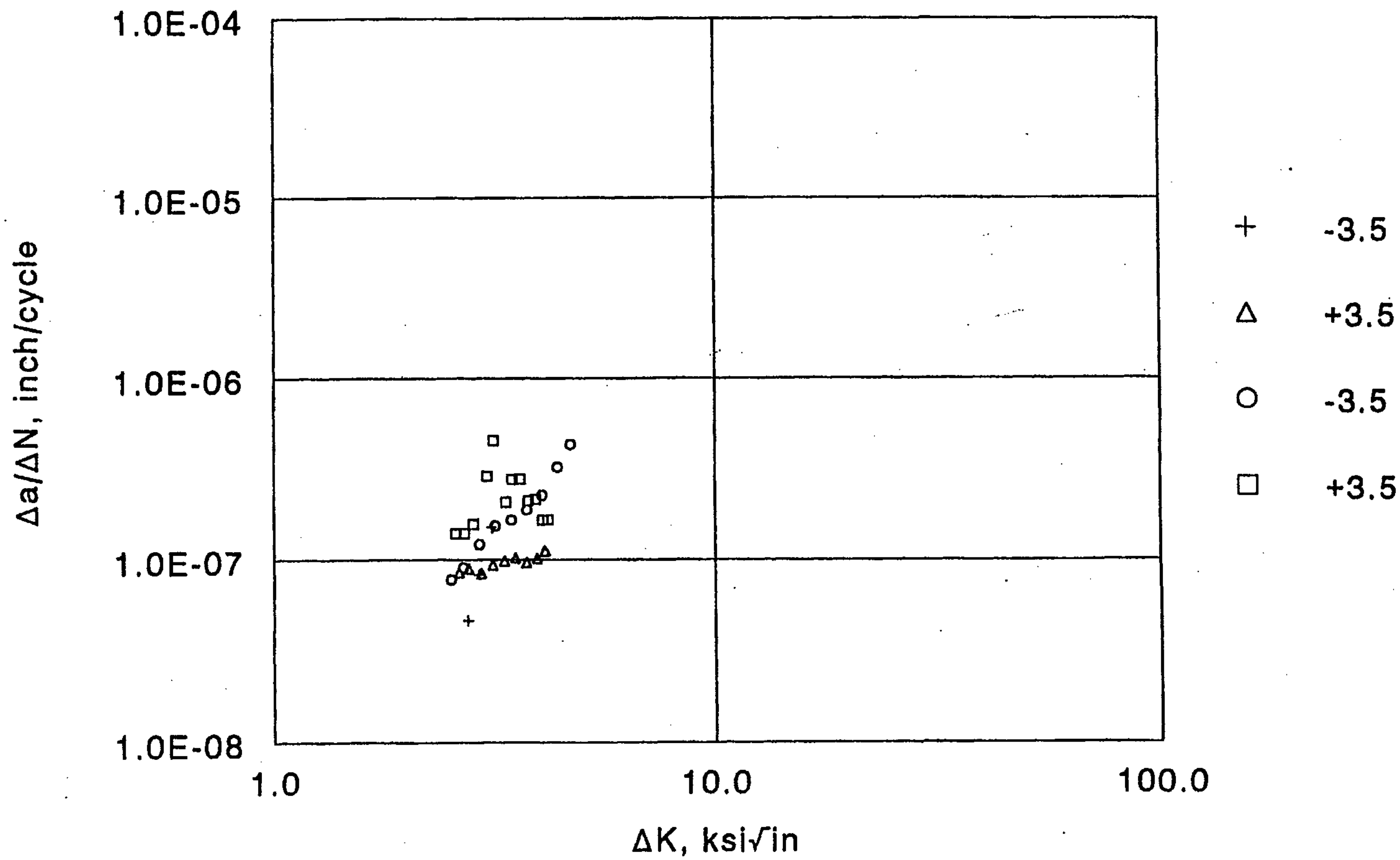
Comments

Date of test: 12-14-1997

Specimen Id. CC1C

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5
	657.5	1.0480	5				
129	672.1	1.0608	19488	0.0282	43446	6.501E-07	6.25
134	689.7	1.0762	43451	0.0361	40448	8.923E-07	6.65
139	713.5	1.0969	59936	0.0393	23657	1.661E-06	7.09
144	735.1	1.1155	67109	0.0348	17014	2.047E-06	7.59
149	754.0	1.1317	76950	0.0317	17503	1.810E-06	8.09
153	772.2	1.1472	84612	0.0308	17626	1.746E-06	8.58
159	790.3	1.1625	94576	0.0377	19369	1.948E-06	9.20
163	817.0	1.1849	103980	0.0385	12608	3.053E-06	9.75
169	836.3	1.2010	107183	0.0336	6255	5.373E-06	10.50
174	857.5	1.2186	110235	0.0328	5664	5.791E-06	11.13
179	876.1	1.2338	112847	0.0327	4398	7.434E-06	11.87
183	897.5	1.2512	114633	0.0337	3373	1.001E-05	12.58
188	917.6	1.2676	116220	0.0346	2896	1.193E-05	13.41
192	938.1	1.2858	117530	0.0298	1816	1.641E-05	14.08
	950.4	1.2973	118036				

Fairchild DTA 06-8520 CC2
2014-T65121 EXTR CT SPEC. R=0.8



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC2	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.553
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.518
Width	1.995	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	500.0	Stress ratio (R)	0.80
Final a (in)	0.614	Kmax	16.42

Test Parameters

Initial a (in)	0.614	Initial K	16.40
K-gradient	-3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis	Codes	
0.886000	0.282770	KRPP	1	0
4.640000	0.490560			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
50.94	0.632	0.632	0.000	1.357
130.54	0.680	0.680	0.000	0.907

Comments

Date of test: 12-16-1997

Specimen Id. CC2 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	50.9	0.6318	9				
459	66.1	0.6464	78443	0.0302	201476	1.501E-07	3.15
422	86.5	0.6620	201484	0.0267	321480	8.298E-08	2.94
393	107.1	0.6731	399923	0.0147	317380	4.642E-08	2.77
	116.9	0.6767	518864				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC2A	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.553
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.518
Width	1.995	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	500.0	Stress ratio (R)	0.80
Final a (in)	0.614	Kmax	16.42

Test Parameters

Initial a (in)	0.680	Initial K	12.50
K-gradient	3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff
0.886000	0.276820
4.640000	0.490560
-13.320000	0.000000
14.720000	0.000000
-5.600000	0.000000
0.000000	0.000000

Analysis	Codes	
KRPP	1	0

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
131.37	0.680	0.680	0.000	0.994
333.77	0.788	0.789	0.000	0.723

Comments

Date of test: 12-17-1997

Specimen Id. CC2A

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	131.4	0.6800	33				
364	143.7	0.6896	146929	0.0265	312882	8.468E-08	2.65
377	166.5	0.7065	312915	0.0308	345515	8.920E-08	2.78
395	187.0	0.7205	492444	0.0270	322234	8.380E-08	2.97
413	207.7	0.7335	635149	0.0245	261307	9.361E-08	3.16
431	227.6	0.7449	753752	0.0223	226967	9.842E-08	3.35
450	248.5	0.7558	862116	0.0205	200374	1.022E-07	3.55
471	268.9	0.7654	954126	0.0181	188106	9.629E-08	3.76
492	289.6	0.7739	1050222	0.0161	158383	1.015E-07	3.97
508	310.5	0.7815	1112509	0.0108	96344	1.118E-07	4.13
	320.6	0.7847	1146566				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC2B	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.553
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.518
Width	1.995	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	500.0	Stress ratio (R)	0.80
Final a (in)	0.614	Kmax	16.42

Test Parameters

Initial a (in)	0.789	Initial K	25.00
K-gradient	-3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff
0.886000	0.227670
4.640000	0.490560
-13.320000	0.000000
14.720000	0.000000
-5.600000	0.000000
0.000000	0.000000

Analysis Codes		
KRPP	1	0

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
339.13	0.788	0.789	0.000	1.007
541.49	0.902	0.902	0.000	0.846

Comments

Date of test: 12-18-1997

Specimen Id. CC2B

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	339.7	0.7889	86				
563	354.1	0.7991	26913	0.0246	56864	4.325E-07	4.72
519	375.2	0.8135	56949	0.0273	84182	3.239E-07	4.42
471	395.1	0.8264	111095	0.0254	112192	2.266E-07	4.08
428	415.3	0.8389	169142	0.0247	130720	1.886E-07	3.77
388	436.0	0.8511	241815	0.0232	139951	1.655E-07	3.48
352	455.9	0.8621	309093	0.0218	141648	1.536E-07	3.20
319	476.4	0.8728	383463	0.0207	170920	1.211E-07	2.95
290	496.7	0.8828	480013	0.0192	212994	9.015E-08	2.71
269	516.8	0.8920	596458	0.0138	178282	7.768E-08	2.54
	527.4	0.8966	658294				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CC2C	Geometry	CT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.553
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.124	Notch depth	0.518
Width	1.995	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	500.0	Stress ratio (R)	0.80
Final a (in)	0.614	Kmax	16.42

Test Parameters

Initial a (in)	0.902	Initial K	12.50
K-gradient	3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
0.886000	0.185250	KRPP	1	0
4.640000	0.490560			
-13.320000	0.000000			
14.720000	0.000000			
-5.600000	0.000000			
0.000000	0.000000			

Visual Observations

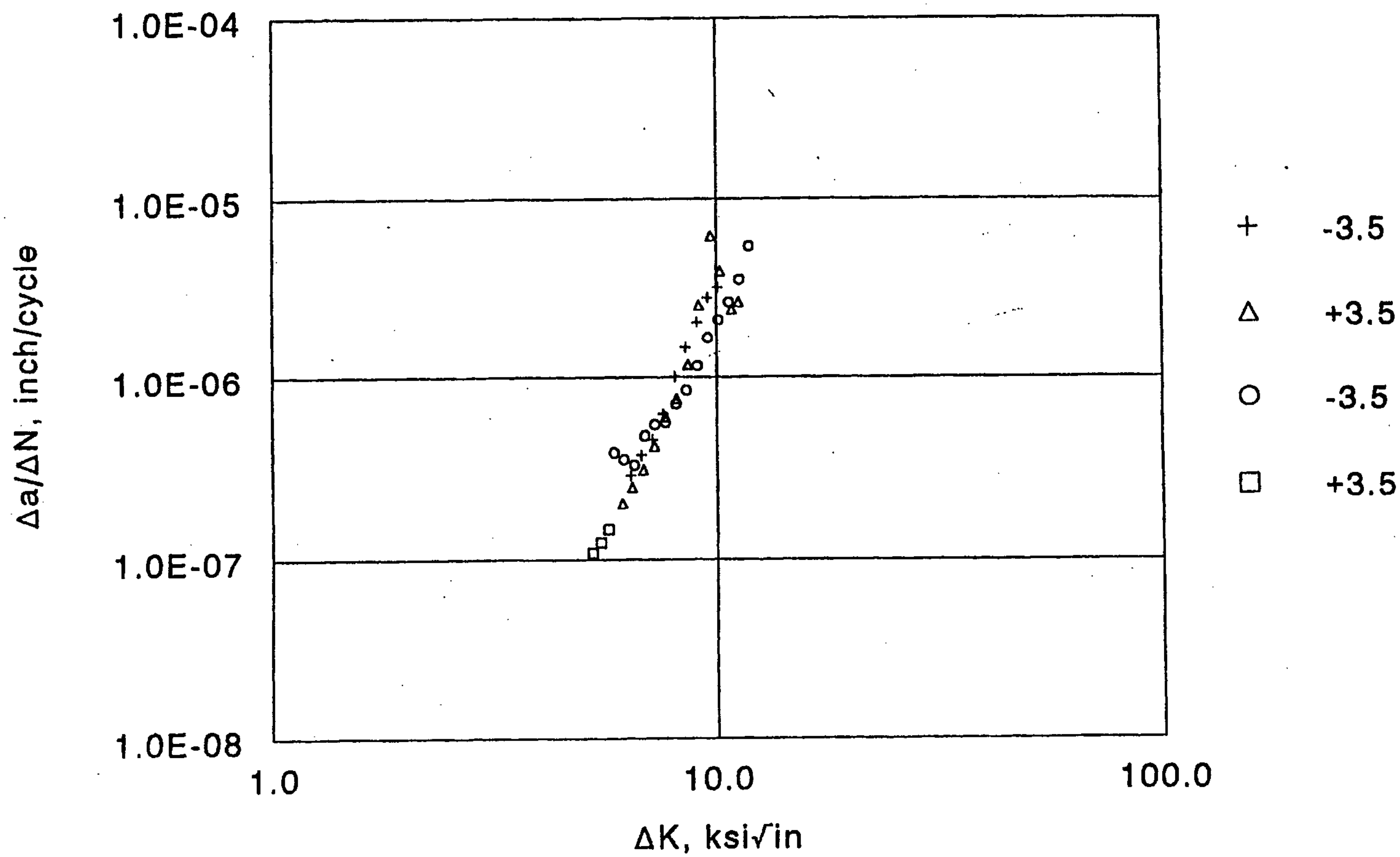
PD	Crack (PD)	Crack (visual)	Error	PDAF
541.26	0.902	0.902	0.000	1.006
795.97	0.967	0.967	0.000	0.768

Comments

Date of test: 12-18-1997

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	541.8	0.9027	17				
267	556.4	0.9097	43485	0.0154	110626	1.394E-07	2.60
277	575.5	0.9182	110643	0.0171	122202	1.396E-07	2.73
288	596.6	0.9267	165687	0.0155	98782	1.571E-07	2.86
304	615.4	0.9337	209425	0.0184	63786	2.888E-07	3.07
312	651.2	0.9451	229473	0.0136	29696	4.567E-07	3.17
329	658.7	0.9472	239121	0.0071	34078	2.083E-07	3.38
338	678.3	0.9522	263551	0.0098	35314	2.776E-07	3.50
350	700.4	0.9570	274435	0.0081	29020	2.793E-07	3.64
364	718.8	0.9603	292571	0.0062	29302	2.111E-07	3.81
376	738.7	0.9632	303737	0.0049	22863	2.159E-07	3.95
388	757.4	0.9653	315434	0.0034	20272	1.659E-07	4.09
399	774.5	0.9666	324009	0.0020	11907	1.660E-07	4.21
	788.3	0.9673	327341				

Fairchild DTA 06-8520 CM1
2014-T65121 EXTR CT SPEC. R= -0.2



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM1	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.364
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.114	Notch depth	0.403
Width	1.700	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.459	Kmax	10.74

Test Parameters

Initial a (in)	0.459	Initial K	10.70
K-gradient	-3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.223282	KRCP	1	0
	0.578970			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
80.58	0.454	0.454	0.000	0.936
257.14	0.641	0.641	0.000	1.034

Comments

Date of test: 12-18-1997

Specimen Id. CM1 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	80.6	0.4538	12				
3055	94.7	0.4675	4092	0.0303	9287	3.265E-06	10.08
2838	111.5	0.4841	9299	0.0341	11932	2.855E-06	9.55
2624	128.8	0.5016	16024	0.0349	16916	2.061E-06	9.02
2417	145.7	0.5190	26215	0.0364	24558	1.482E-06	8.49
2238	163.9	0.5380	40582	0.0363	36028	1.008E-06	8.03
2062	180.1	0.5553	62243	0.0364	57824	6.286E-07	7.56
1911	197.7	0.5743	98405	0.0379	83507	4.535E-07	7.15
1763	214.8	0.5932	145750	0.0387	103274	3.749E-07	6.75
1632	232.5	0.6131	201679	0.0391	135016	2.899E-07	6.38
	249.4	0.6323	280766				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM1A	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.364
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.114	Notch depth	0.403
Width	1.700	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.459	Kmax	10.74

Test Parameters

Initial a (in)	0.641	Initial K	5.80
K-gradient	3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.228290	KRCP	1	0
	0.578970			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
257.50	0.641	0.641	0.000	0.999
480.61	0.834	0.834	0.000	0.942

Comments

Date of test: 12-19-1997

Specimen Id. CM1A **Page 1**

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	257.5	0.6413	6				
1491	269.9	0.6527	62443	0.0275	134667	2.039E-07	6.11
1545	287.6	0.6688	134673	0.0317	126773	2.501E-07	6.42
1611	305.0	0.6844	189216	0.0312	100539	3.107E-07	6.81
1679	322.5	0.7000	235212	0.0309	73765	4.183E-07	7.22
1750	339.8	0.7152	262981	0.0301	49803	6.036E-07	7.64
1826	356.8	0.7301	285015	0.0302	39666	7.610E-07	8.10
1907	374.6	0.7454	302647	0.0316	26743	1.180E-06	8.60
1988	393.5	0.7616	311757	0.0305	11826	2.576E-06	9.11
2080	410.4	0.7759	314473	0.0298	4751	6.281E-06	9.69
2159	429.0	0.7915	316509	0.0271	6776	3.992E-06	10.19
2256	442.8	0.8029	321248	0.0261	10684	2.439E-06	10.82
2318	460.6	0.8175	327193	0.0216	8046	2.683E-06	11.23
	469.2	0.8245	329295				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM1B	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.364
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.114	Notch depth	0.403
Width	1.700	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.459	Kmax	10.74

Test Parameters

Initial a (in)	0.834	Initial K	12.50
K-gradient	-3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.212230	KRCP	1	0
	0.578970			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
481.21	0.834	0.834	0.000	0.999
746.94	1.154	1.155	0.000	1.080

Comments

Date of test: 12-21-1997

Specimen Id. **CM1B** **Page 1**

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	481.2	0.8338	9				
2355	494.5	0.8488	1900	0.0343	6242	5.494E-06	11.86
2200	511.4	0.8681	6251	0.0392	10915	3.591E-06	11.28
2037	528.7	0.8879	12815	0.0399	14868	2.684E-06	10.67
1886	545.9	0.9080	21120	0.0402	18936	2.122E-06	10.09
1746	563.1	0.9281	31750	0.0403	24028	1.677E-06	9.54
1616	580.2	0.9483	45148	0.0407	35068	1.161E-06	9.03
1492	597.4	0.9688	66818	0.0425	50239	8.469E-07	8.53
1382	615.7	0.9908	95387	0.0421	59184	7.111E-07	8.08
1278	632.3	1.0109	126003	0.0402	71384	5.625E-07	7.65
1181	648.7	1.0310	166771	0.0425	77524	5.487E-07	7.24
1094	666.9	1.0535	203527	0.0438	92065	4.761E-07	6.87
1010	684.1	1.0748	258836	0.0425	128468	3.308E-07	6.50
932	701.0	1.0960	331995	0.0438	123551	3.544E-07	6.16
862	718.9	1.1186	382387	0.0444	114852	3.866E-07	5.85
	736.0	1.1404	446847				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM1C	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.364
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.114	Notch depth	0.403
Width	1.700	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.459	Kmax	10.74

Test Parameters

Initial a (in)	1.155	Initial K	5.00
K-gradient	3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.246650	KRCP	1	0
	0.578970			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

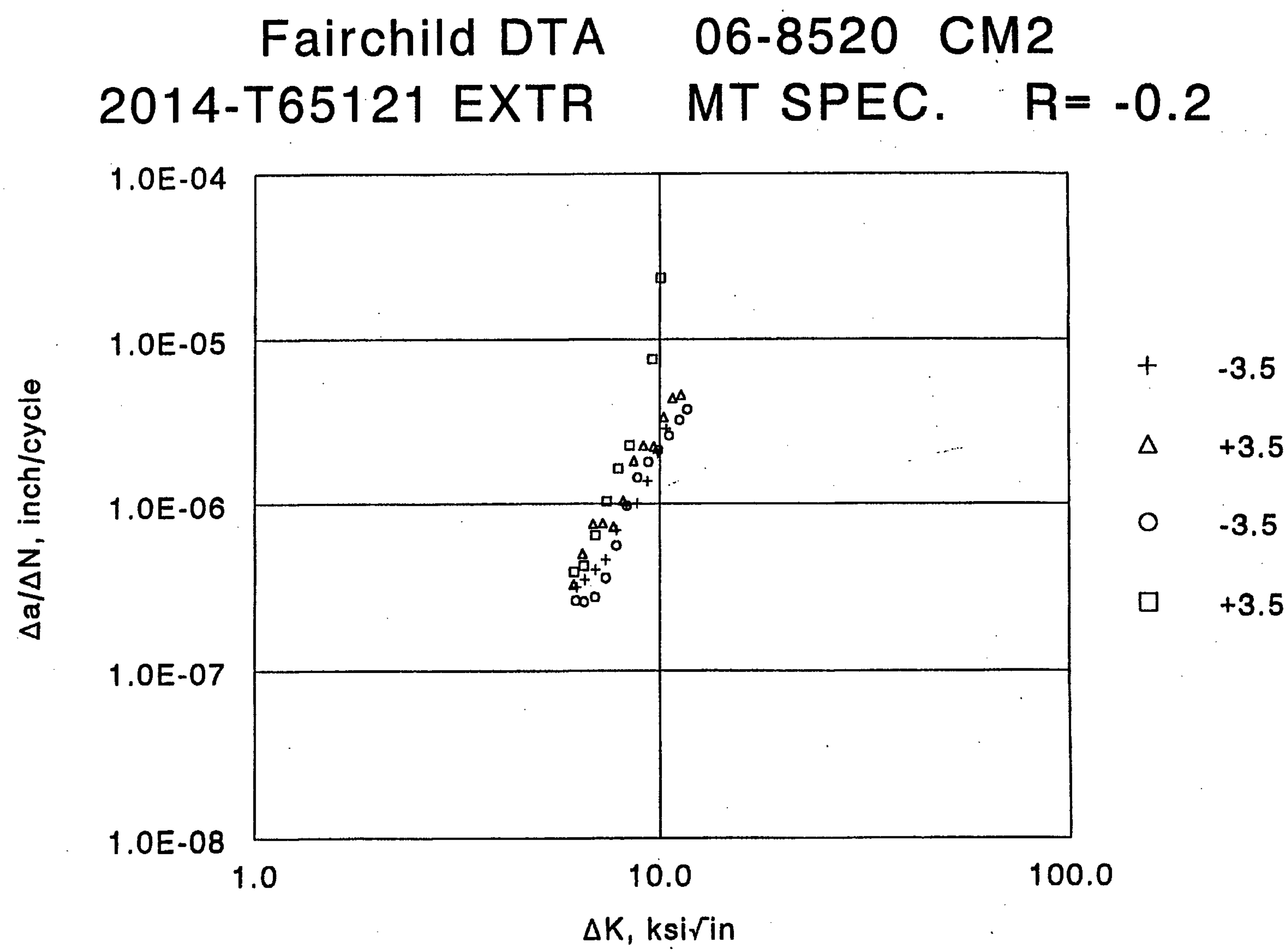
PD	Crack (PD)	Crack (visual)	Error	PDAF
747.19	1.154	1.155	0.000	1.000
814.34	1.192	1.192	0.000	0.964

Comments

Date of test: 12-22-1997

Specimen Id. **CM1C** **Page 1**

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	747.2	1.1545	9				
729	760.0	1.1620	76931	0.0177	162558	1.088E-07	5.23
753	777.8	1.1722	162567	0.0195	156917	1.241E-07	5.46
775	794.6	1.1814	233848	0.0143	97977	1.463E-07	5.68
	804.0	1.1865	260544				


Fairchild DTA 06-8520 CM2
2014-T65121 EXTR MT SPEC. R= -0.2
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0
10.0
100.0
Δa/ΔN, inch/cycle
ΔK, ksi√in
+ -3.5
Δ +3.5
○ -3.5
□ +3.5

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM2	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.350
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.105	Notch depth	0.405
Width	1.699	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3050.0	Stress ratio (R)	-0.20
Final a (in)	0.476	Kmax	11.00

Test Parameters

Initial a (in)	0.476	Initial K	11.00
K-gradient	-3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.208740	KRCP	1	0
	0.579310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
124.13	0.476	0.476	0.000	0.993
307.92	0.654	0.654	0.000	0.987

Comments

Date of test: 12-23-1997

Specimen Id. CM2 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	125.5	0.4774	287				
2825	137.2	0.4887	3761	0.0274	9480	2.894E-06	10.38
2639	153.7	0.5048	9767	0.0332	16269	2.038E-06	9.87
2440	171.3	0.5219	20030	0.0339	24645	1.376E-06	9.31
2255	188.7	0.5387	34412	0.0328	32596	1.007E-06	8.78
2080	205.2	0.5547	52625	0.0332	34098	9.744E-07	8.26
1927	223.0	0.5719	68509	0.0335	48494	6.913E-07	7.80
1777	239.9	0.5882	101119	0.0334	72894	4.582E-07	7.33
1645	257.6	0.6053	141403	0.0336	84285	3.988E-07	6.91
1520	274.7	0.6218	185404	0.0329	94112	3.493E-07	6.51
1433	291.7	0.6382	235516	0.0252	79951	3.155E-07	6.22
	300.9	0.6471	265354				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM2A	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.350
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.105	Notch depth	0.405
Width	1.699	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3050.0	Stress ratio (R)	-0.20
Final a (in)	0.476	Kmax	11.00

Test Parameters

Initial a (in)	0.654	Initial K	5.80
K-gradient	3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.206430	KRCP	1	0
	0.579310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
308.20	0.654	0.654	0.000	0.999
538.84	0.853	0.854	0.000	0.948

Comments

Date of test: 12-28-1997

Specimen Id. CM2A   Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	308.2	0.6538	9				
1357	320.3	0.6648	43198	0.0272	83304	3.265E-07	6.10
1406	338.1	0.6810	83313	0.0321	64748	4.955E-07	6.42
1469	355.8	0.6969	107946	0.0325	43071	7.555E-07	6.82
1528	374.5	0.7135	126384	0.0302	39946	7.571E-07	7.21
1597	389.9	0.7272	147892	0.0291	40390	7.215E-07	7.66
1662	407.6	0.7427	166774	0.0309	29586	1.043E-06	8.10
1737	425.2	0.7580	177477	0.0316	17276	1.832E-06	8.60
1808	444.2	0.7743	184050	0.0298	13120	2.274E-06	9.10
1888	460.0	0.7878	190597	0.0277	12278	2.254E-06	9.65
1970	476.7	0.8020	196327	0.0304	8928	3.401E-06	10.22
2047	496.1	0.8182	199525	0.0289	6530	4.427E-06	10.78
2122	511.3	0.8309	202857	0.0213	4612	4.614E-06	11.32
	521.7	0.8395	204137				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM2B	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.350
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.105	Notch depth	0.405
Width	1.699	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3050.0	Stress ratio (R)	-0.20
Final a (in)	0.476	Kmax	11.00

Test Parameters

Initial a (in)	0.854	Initial K	12.50
K-gradient	-3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.190180	KRCP	1	0
	0.579310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
543.01	0.853	0.854	0.000	0.992
760.15	1.051	1.051	0.000	0.973

Comments

Date of test: 12-29-1997

Specimen Id. CM2B Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	543.0	0.8535	11				
2115	551.7	0.8615	1992	0.0241	6394	3.771E-06	11.72
1996	569.0	0.8776	6405	0.0318	9746	3.261E-06	11.20
1847	586.1	0.8933	11738	0.0317	12064	2.631E-06	10.54
1709	603.5	0.9093	18468	0.0320	14919	2.143E-06	9.92
1582	620.9	0.9253	26656	0.0314	17320	1.811E-06	9.34
1462	637.8	0.9407	35789	0.0314	21614	1.454E-06	8.78
1353	655.4	0.9567	48270	0.0317	32640	9.713E-07	8.27
1251	672.7	0.9724	68429	0.0311	56031	5.557E-07	7.78
1157	689.7	0.9878	104301	0.0310	86626	3.574E-07	7.32
1070	707.0	1.0034	155055	0.0310	112255	2.764E-07	6.88
989	724.2	1.0189	216556	0.0312	119903	2.601E-07	6.47
931	741.7	1.0346	274958	0.0236	89454	2.639E-07	6.18
	750.6	1.0425	306010				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM2C	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.350
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.105	Notch depth	0.405
Width	1.699	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3050.0	Stress ratio (R)	-0.20
Final a (in)	0.476	Kmax	11.00

Test Parameters

Initial a (in)	1.051	Initial K	5.80
K-gradient	3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.178280	KRCP	1	0
	0.579310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
760.27	1.051	1.051	0.000	1.000
935.32	1.265	1.265	0.000	1.045

Comments

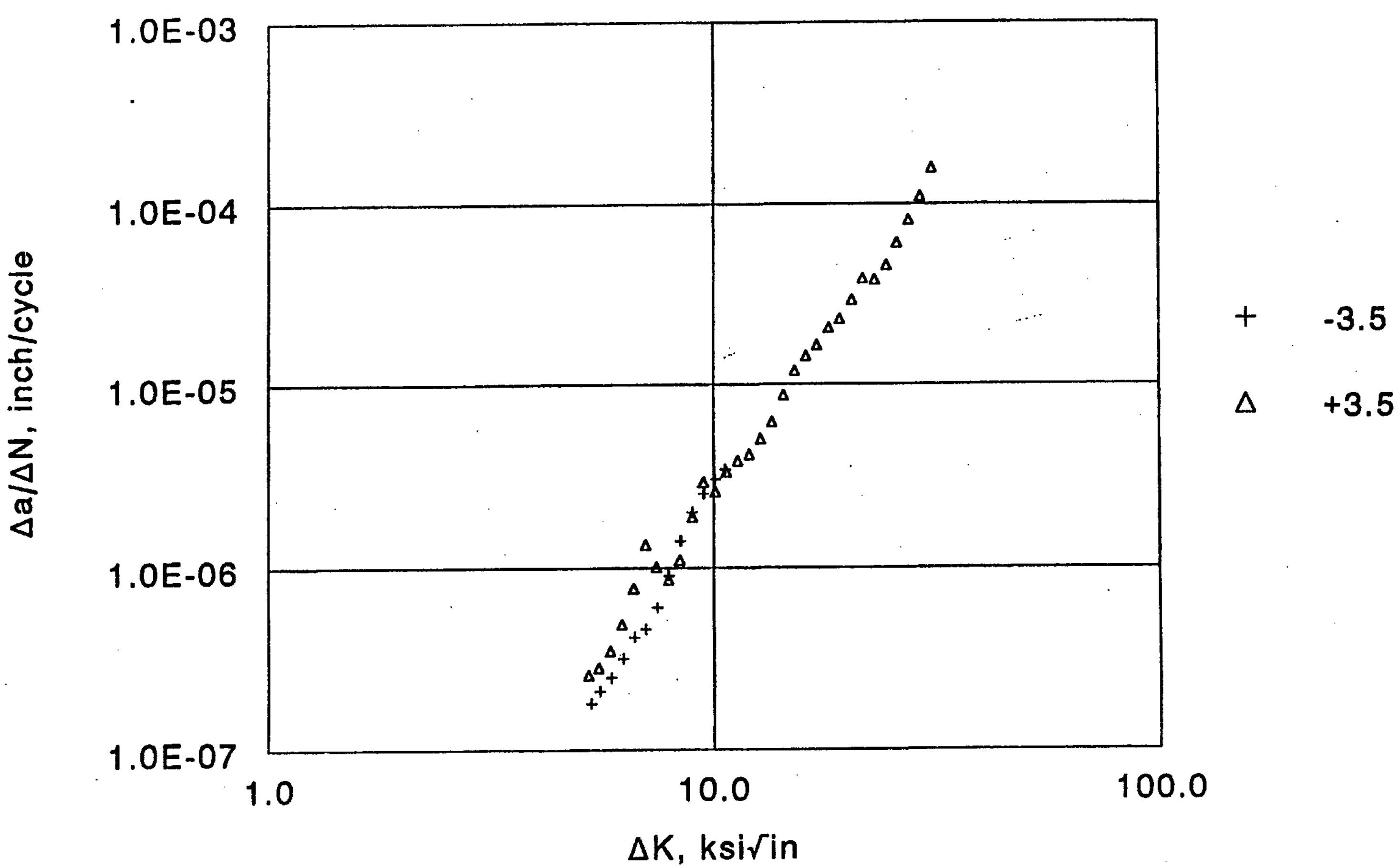
Date of test: 12-30-1997

Specimen Id. CM2C Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	760.3	1.0510	25				
884	772.2	1.0650	31232	0.0347	89417	3.880E-07	6.12
915	789.5	1.0857	89442	0.0420	100117	4.199E-07	6.47
953	807.4	1.1071	131348	0.0438	68246	6.420E-07	6.92
991	826.0	1.1295	157688	0.0429	41398	1.035E-06	7.38
1030	842.8	1.1500	172746	0.0400	24141	1.657E-06	7.87
1070	858.8	1.1695	181828	0.0418	18265	2.287E-06	8.41
1153	876.8	1.1917	191012	0.0875	11533	7.590E-06	9.58
1183	929.0	1.2570	193361	0.0733	3084	2.375E-05	10.04
	935.3	1.2650	194096				

Fairchild DTA 06-8520 CM3

2014-T65121 EXTR MT SPEC. R= -0.2



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM3	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.345
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.109	Notch depth	0.404
Width	1.701	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.492	Kmax	11.64

Test Parameters

Initial a (in)	0.492	Initial K	11.20
K-gradient	-3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.213290	KRCP	1	0
	0.578630			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
131.98	0.492	0.492	0.000	0.997
366.06	0.727	0.727	0.000	1.011

Comments

Date of test: 01-05-1998

Specimen Id. CM3 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	132.0	0.4923	9				
2952	145.1	0.5053	3457	0.0300	8766	3.425E-06	10.61
2755	162.3	0.5223	8774	0.0337	11075	3.039E-06	10.08
2544	179.0	0.5389	14532	0.0339	13384	2.533E-06	9.50
2354	196.4	0.5562	22159	0.0343	17101	2.007E-06	8.96
2175	213.5	0.5733	31633	0.0342	24444	1.400E-06	8.45
2009	230.7	0.5904	46602	0.0348	38352	9.069E-07	7.96
1859	248.2	0.6080	69985	0.0347	57610	6.024E-07	7.51
1717	265.3	0.6252	104212	0.0345	75637	4.565E-07	7.07
1589	282.6	0.6426	145621	0.0350	84652	4.129E-07	6.67
1472	300.0	0.6601	188864	0.0343	109454	3.133E-07	6.29
1359	316.6	0.6769	255075	0.0349	141131	2.472E-07	5.92
1259	334.5	0.6950	329995	0.0358	171276	2.091E-07	5.59
1187	352.0	0.7127	426351	0.0262	146036	1.795E-07	5.34
	360.4	0.7212	476031				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CM3A	Geometry	MT
Contract #	06-8520	Orientation	LT
Material	2014-T6511	Yield (ksi)	60.7
Temperature (F)	75	Initial A0 (PD)	0.345
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.109	Notch depth	0.404
Width	1.701	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	3300.0	Stress ratio (R)	-0.20
Final a (in)	0.492	Kmax	11.64

Test Parameters

Initial a (in)	0.727	Initial K	5.00
K-gradient	3.50	Stress ratio (R)	-0.20

K Coeff	PD Coeff	Analysis Codes		
	0.215586	KRCP	1	0
	0.578630			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

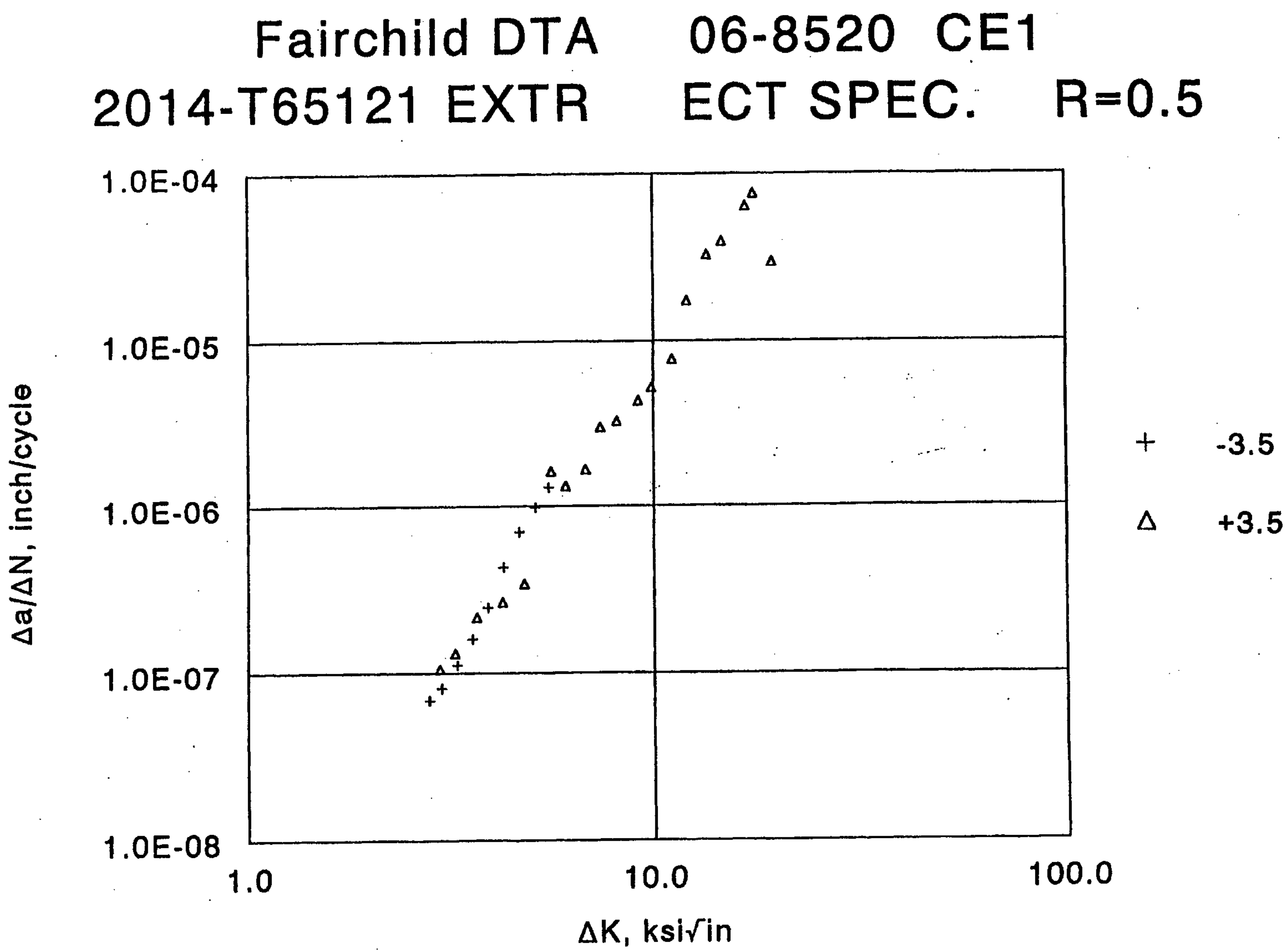
PD	Crack (PD)	Crack (visual)	Error	PDAF
366.10	0.725	0.727	0.002	0.994
632.05	0.984	0.977	-.007	0.992
878.64	1.223	1.228	0.005	0.990

Comments

Date of test: 01-06-1998

Specimen Id. CM3A Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	366.1	0.7251	384				
1130	379.3	0.7379	55125	0.0301	118310	2.543E-07	5.26
1172	397.0	0.7552	118694	0.0340	121744	2.796E-07	5.54
1223	414.2	0.7720	176869	0.0341	98363	3.462E-07	5.89
1276	431.9	0.7892	217058	0.0344	70659	4.865E-07	6.25
1331	449.5	0.8063	247527	0.0339	44024	7.704E-07	6.64
1390	466.7	0.8232	261081	0.0345	25824	1.337E-06	7.06
1446	484.9	0.8409	273351	0.0330	32689	1.008E-06	7.47
1511	500.6	0.8561	293770	0.0329	38357	8.584E-07	7.95
1571	518.8	0.8738	311708	0.0343	31243	1.097E-06	8.41
1642	535.8	0.8904	325014	0.0342	18081	1.893E-06	8.95
1708	554.0	0.9080	329789	0.0333	11417	2.920E-06	9.48
1782	570.1	0.9237	336431	0.0324	12501	2.589E-06	10.07
1855	587.2	0.9404	342290	0.0337	10156	3.317E-06	10.67
1931	604.7	0.9574	346587	0.0333	8723	3.815E-06	11.31
2012	621.5	0.9737	351013	0.0330	7989	4.132E-06	12.00
2096	638.7	0.9904	354575	0.0342	6793	5.034E-06	12.74
2183	656.7	1.0079	357806	0.0342	5470	6.253E-06	13.51
2275	673.9	1.0246	360045	0.0334	3812	8.762E-06	14.35
2366	691.1	1.0413	361618	0.0329	2777	1.185E-05	15.21
2465	707.8	1.0575	362822	0.0338	2357	1.434E-05	16.16
2561	726.0	1.0751	363975	0.0338	2040	1.656E-05	17.11
2669	742.7	1.0913	364862	0.0339	1648	2.060E-05	18.21
2768	761.0	1.1090	365623	0.0327	1417	2.308E-05	19.24
2886	776.4	1.1240	366279	0.0333	1132	2.943E-05	20.50
2991	795.4	1.1423	366754	0.0347	900	3.860E-05	21.67
3109	812.3	1.1587	367179	0.0324	847	3.819E-05	23.02
3231	828.8	1.1747	367601	0.0340	740	4.591E-05	24.46
3346	847.4	1.1927	367918	0.0337	553	6.106E-05	25.86
3475	863.6	1.2084	368154	0.0324	397	8.162E-05	27.49
3601	880.8	1.2250	368315	0.0341	310	1.100E-04	29.14
3732	898.8	1.2425	368464	0.0351	223	1.578E-04	30.94
	916.8	1.2602	368537				



Fairchild DTA 06-8520 CE1
2014-T65121 EXTR ECT SPEC. R=0.5
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
Δa/ΔN, inch/cycle
1.0
10.0
100.0
ΔK, ksi√in
+ -3.5
Δ +3.5

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE1	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.576
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.760	Kmax	11.79

Test Parameters

Initial a (in)	0.760	Initial K	12.00
K-gradient	-3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.237470	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
139.74	0.759	0.760	0.000	0.996
347.07	0.999	0.999	0.000	0.987

Comments

Date of test: 01-21-1998

Specimen Id. CE1 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	139.7	0.7595	6				
548	155.3	0.7777	11881	0.0433	33230	1.303E-06	5.54
495	176.9	0.8028	33236	0.0493	50020	9.849E-07	5.14
438	197.6	0.8269	61901	0.0494	70453	7.017E-07	4.69
389	219.4	0.8522	103688	0.0499	115354	4.325E-07	4.30
345	240.6	0.8768	177255	0.0488	196114	2.487E-07	3.94
306	261.5	0.9010	299802	0.0490	305322	1.605E-07	3.60
272	283.0	0.9258	482577	0.0489	439348	1.113E-07	3.30
241	303.9	0.9499	739150	0.0484	598821	8.084E-08	3.02
220	325.0	0.9742	1081398	0.0371	540329	6.868E-08	2.82
	336.2	0.9870	1279479				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE1A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.576
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.760	Kmax	11.79

Test Parameters

Initial a (in)	0.999	Initial K	5.30
K-gradient	3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.218000	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

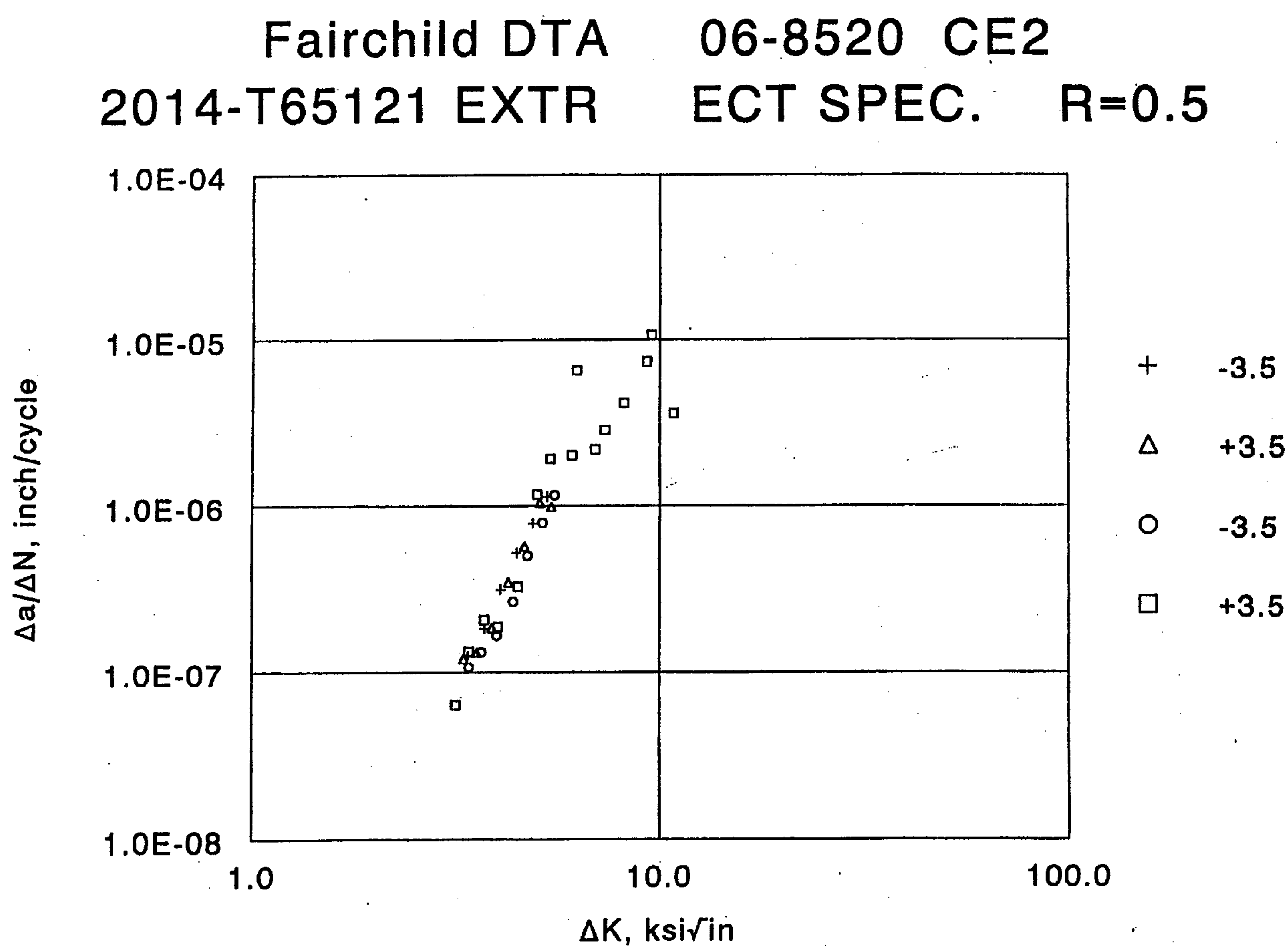
PD	Crack (PD)	Crack (visual)	Error	PDAF
347.16	0.964	0.999	0.036	1.018
619.73	1.295	1.164	-.131	1.023
876.25	1.610	1.706	0.096	1.028

Comments

Date of test: 01-23-1998

Specimen Id. CE1A Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	388.2	1.0136	1080				
212	405.7	1.0347	231489	0.0528	500066	1.055E-07	2.99
224	431.7	1.0663	501145	0.0602	458825	1.311E-07	3.26
241	455.3	1.0949	690314	0.0691	318767	2.169E-07	3.69
263	488.6	1.1354	819912	0.0974	363821	2.676E-07	4.27
283	535.3	1.1923	1054136	0.0869	253439	3.430E-07	4.83
309	560.0	1.2224	1073351	0.0602	36941	1.630E-06	5.61
324	584.7	1.2525	1091076	0.0476	35935	1.326E-06	6.09
346	599.0	1.2700	1109286	0.0517	30847	1.678E-06	6.80
363	627.0	1.3042	1121923	0.0654	21543	3.034E-06	7.39
382	652.5	1.3354	1130829	0.0507	15285	3.315E-06	8.11
409	668.4	1.3549	1137209	0.0591	13500	4.378E-06	9.16
427	700.7	1.3945	1144328	0.0641	12144	5.277E-06	9.89
455	720.7	1.4190	1149352	0.0538	6947	7.741E-06	11.13
476	744.6	1.4482	1151275	0.0538	3082	1.744E-05	12.12
506	764.5	1.4727	1152434	0.0630	1909	3.299E-05	13.62
529	795.8	1.5112	1153184	0.0645	1627	3.966E-05	14.87
566	817.0	1.5373	1154061	0.0657	1026	6.400E-05	17.02
578	849.1	1.5769	1154210	0.0382	500	7.636E-05	17.76
608	848.0	1.5754	1154561	0.0199	667	2.987E-05	19.74
	865.3	1.5968	1154877				



Fairchild DTA 06-8520 CE2
2014-T65121 EXTR ECT SPEC. R=0.5
1.0E-04
1.0E-05
1.0E-06
1.0E-07
1.0E-08
Δa/ΔN, inch/cycle
1.0
10.0
100.0
ΔK, ksi√in
+ -3.5
Δ +3.5
○ -3.5
□ +3.5

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE2	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.539
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.737	Kmax	11.43

Test Parameters

Initial a (in)	0.737	Initial K	11.50
K-gradient	-3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.219250	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
159.60	0.737	0.737	0.000	0.998
307.72	0.898	0.898	0.000	0.961

Comments

Date of test: 01-15-1998

Specimen Id. CE2 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	159.6	0.7370	6				
543	175.6	0.7550	13269	0.0414	36496	1.135E-06	5.31
489	196.6	0.7784	36502	0.0468	59548	7.854E-07	4.91
434	217.7	0.8017	72817	0.0467	89919	5.196E-07	4.49
385	239.2	0.8251	126421	0.0465	148354	3.133E-07	4.10
342	260.6	0.8482	221171	0.0447	245600	1.822E-07	3.75
303	281.0	0.8699	372021	0.0448	359374	1.246E-07	3.42
	302.9	0.8930	580545				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE2A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.539
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.737	Kmax	11.43

Test Parameters

Initial a (in)	0.898	Initial K	6.20
K-gradient	3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.213520	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
307.67	0.898	0.898	[illegible]	[illegible]
469.67	1.073	[illegible]	[illegible]	[illegible]

Comments

Date of test: 01-15-1998

Specimen Id. CE2A

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da dN (in/cyc)	dK (ksi[in]^.5)
	397.7	0.8980	6				
273	325.0	0.9150	151705	0.0402	333904	1.205E-07	3.33
292	344.0	0.9382	333910	0.0473	361550	1.309E-07	3.60
308	366.0	0.9623	513256	0.0462	250717	1.844E-07	3.91
327	386.4	0.9844	584627	0.0476	137943	3.450E-07	4.28
346	410.1	1.0099	651199	0.0519	90970	5.701E-07	4.68
366	434.8	1.0363	675598	0.0471	45131	1.044E-06	5.11
381	454.5	1.0570	696330	0.0286	28926	9.884E-07	5.44
	461.9	1.0649	704523				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE2B	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.539
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.737	Kmax	11.43

Test Parameters

Initial a (in)	1.073	Initial K	12.00
K-gradient	-3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.206000	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
473.99	1.073	1.073	0.000	0.996
640.99	1.275	1.275	0.000	1.003

Comments

Date of test: 01-18-1998

Specimen Id. CE2B

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	474.0	1.0730	8				
367	487.5	1.0893	10427	0.0394	33950	1.162E-06	5.54
333	506.8	1.1124	33957	0.0470	59286	7.926E-07	5.18
297	526.6	1.1363	69713	0.0496	99180	5.003E-07	4.76
265	547.9	1.1620	133138	0.0486	183014	2.656E-07	4.40
233	566.8	1.1849	252728	0.0518	312694	1.658E-07	4.01
206	590.7	1.2139	445831	0.0564	427524	1.318E-07	3.69
187	613.3	1.2412	680252	0.0398	371747	1.071E-07	3.44
	623.5	1.2537	817578				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE2C	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.539
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.50
Final a (in)	0.737	Kmax	11.43

Test Parameters

Initial a (in)	1.275	Initial K	6.00
K-gradient	3.50	Stress ratio (R)	0.50

K Coeff	PD Coeff	Analysis Codes		
	0.202000	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
652.42	1.275	1.275	0.000	0.998
819.83	1.456	1.457	0.000	0.982

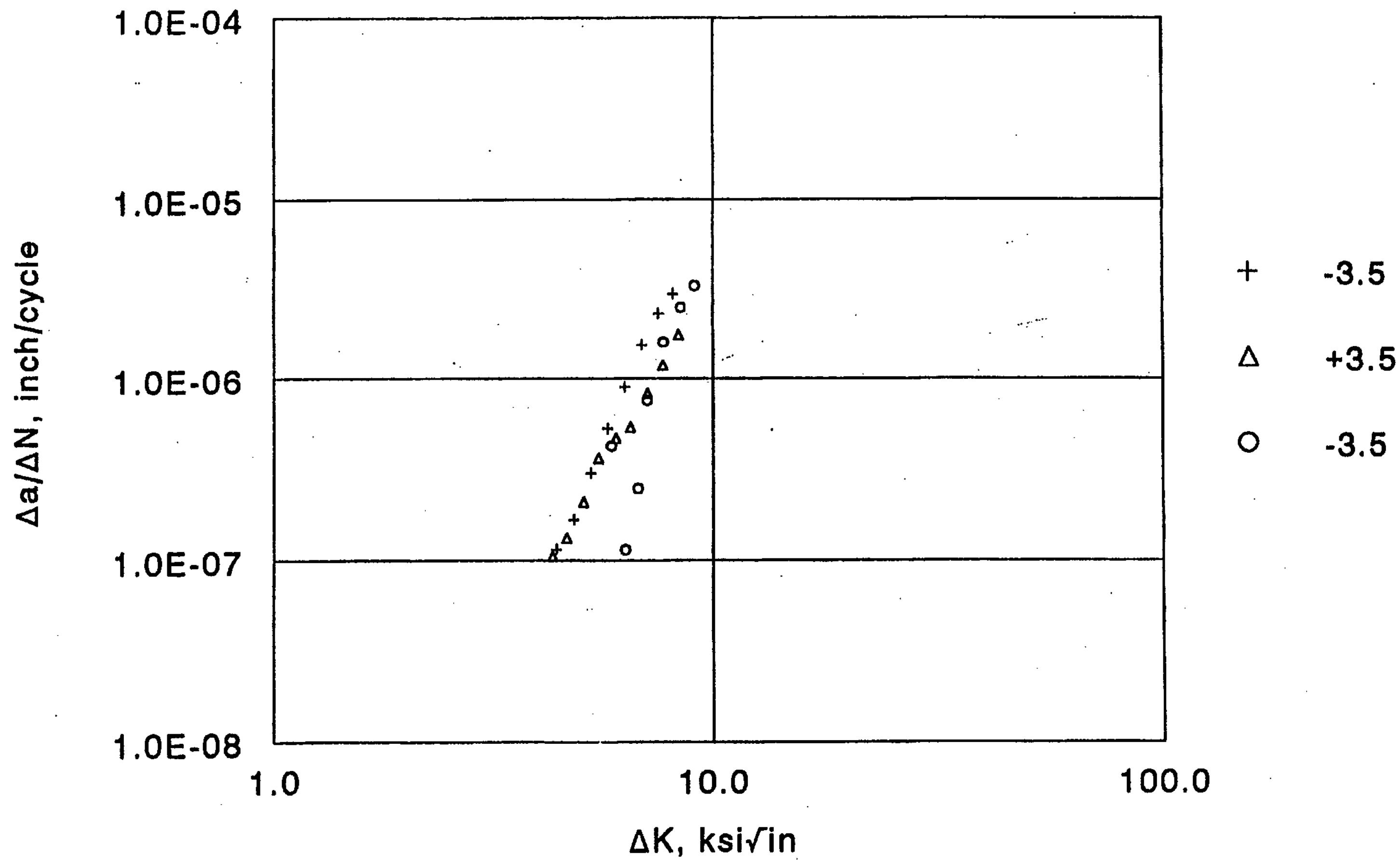
Comments

Date of test: 01-19-1998

Specimen Id. CE2C Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	652.4	1.2750	15				
160	662.2	1.2858	289322	0.0332	524120	6.335E-08	3.19
167	682.6	1.3082	524134	0.0510	381326	1.338E-07	3.43
175	708.8	1.3368	670648	0.0534	258002	2.071E-07	3.74
183	731.6	1.3616	782136	0.0386	206551	1.871E-07	4.04
195	744.4	1.3754	877199	0.0494	150724	3.275E-07	4.52
208	777.3	1.4110	932860	0.0798	68167	1.170E-06	5.03
216	818.7	1.4552	945366	0.0489	25614	1.910E-06	5.41
231	822.8	1.4599	958474	0.0284	14132	2.007E-06	6.12
234	843.2	1.4836	959498	0.0334	5134	6.498E-06	6.27
247	851.6	1.4932	963607	0.0453	20929	2.163E-06	6.96
254	882.2	1.5288	980427	0.0572	20139	2.842E-06	7.35
268	900.9	1.5505	983747	0.0460	11231	4.099E-06	8.17
285	921.9	1.5749	991657	0.0772	10501	7.349E-06	9.30
289	967.4	1.6276	994248	0.0427	3976	1.074E-05	9.54
306	958.7	1.6176	995634	0.0100	2801	3.570E-06	10.83
	976.1	1.6376	997048				

Fairchild DTA 06-8520 CE3
2014-T65121 EXTR ECT SPEC. R=0.2



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE3	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.537
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.618
Width	2.504	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.18

Test Parameters

Initial a (in)	0.717	Initial K	11.00
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.220500	KREP	1	0
	0.471690			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
140.33	0.717	0.717	0.000	0.995
329.82	0.928	0.929	0.000	0.966

Comments

Date of test: 01-12-1998

Specimen Id. CE3 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	140.3	0.7170	6				
531	155.0	0.7339	5128	0.0414	13927	2.975E-06	8.12
479	176.6	0.7584	13933	0.0493	21281	2.315E-06	7.53
425	198.4	0.7831	26409	0.0483	31300	1.544E-06	6.88
377	219.4	0.8068	45232	0.0470	52245	9.003E-07	6.29
335	240.3	0.8302	78654	0.0467	88480	5.283E-07	5.76
297	261.3	0.8535	133713	0.0470	155979	3.013E-07	5.27
264	282.8	0.8771	234633	0.0465	277737	1.676E-07	4.82
234	303.7	0.9001	411450	0.0461	401232	1.150E-07	4.40
	325.0	0.9233	635865				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE3A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.537
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.618
Width	2.504	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.18

Test Parameters

Initial a (in)	0.929	Initial K	5.00
K-gradient	3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.215210	KREP	1	0
	0.471690			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
329.86	0.928	0.929	0.000	1.000
552.00	1.157	1.158	0.000	0.949

Comments

Date of test: 01-13-1998

Specimen Id. CE3A   Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	329.8	0.9284	12				
215	345.9	0.9460	182953	0.0401	381472	1.052E-07	4.31
226	366.9	0.9686	381484	0.0454	342180	1.326E-07	4.64
239	388.3	0.9913	525133	0.0478	228116	2.095E-07	5.07
252	412.1	1.0164	609601	0.0438	120666	3.626E-07	5.49
267	430.0	1.0351	645799	0.0421	90257	4.664E-07	6.01
281	452.7	1.0584	699858	0.0444	82423	5.392E-07	6.49
297	473.4	1.0795	728221	0.0441	53272	8.283E-07	7.09
314	496.3	1.1026	753129	0.0442	37256	1.187E-06	7.69
331	517.6	1.1237	765478	0.0409	23276	1.758E-06	8.36
	537.6	1.1435	776405				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE3B	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.537
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.618
Width	2.504	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.18

Test Parameters

Initial a (in)	1.158	Initial K	12.30
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.201870	KREP	1	0
	0.471690			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
552.32	1.157	1.158	0.000	0.999
723.78	1.354	1.354	0.000	0.993

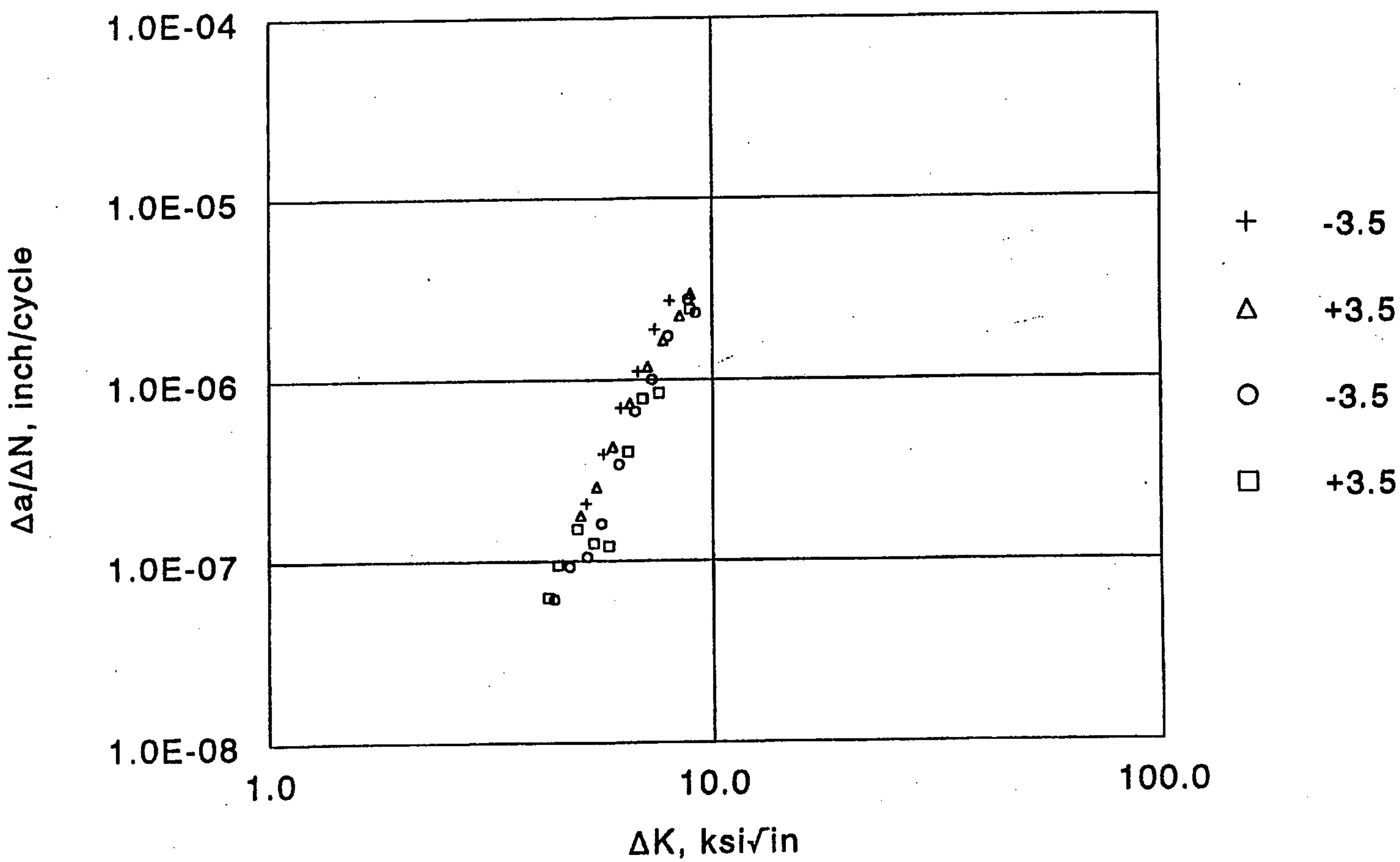
Comments

Date of test: 01-13-1998

Specimen Id. CE3B

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	552.3	1.1575	7				
333	564.7	1.1717	3204	0.0434	13147	3.299E-06	9.08
301	590.0	1.2009	13153	0.0543	21708	2.499E-06	8.46
265	611.8	1.2260	24912	0.0468	29229	1.600E-06	7.71
235	630.7	1.2476	42383	0.0431	56966	7.573E-07	7.08
220	649.4	1.2691	81878	0.0264	106504	2.480E-07	6.75
200	653.7	1.2740	148887	0.0197	171986	1.144E-07	6.31
181	666.6	1.2888	253863	0.0495	116699	4.244E-07	5.87
	697.1	1.3236	265586				

Fairchild DTA 06-8520 CE4
2014-T65121 EXTR ECT SPEC. R=0.2



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE4	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.561
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.623
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.12

Test Parameters

Initial a (in)	0.717	Initial K	10.90
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.231786	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
117.30	0.717	0.717	0.000	0.991
264.58	0.883	0.883	0.000	0.971

Comments

Date of test: 12-31-1997

Specimen Id. CE4

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	117.3	0.7175	5				
527	132.1	0.7345	5932	0.0419	15316	2.733E-06	8.03
476	153.9	0.7594	15321	0.0491	25790	1.903E-06	7.45
422	175.2	0.7836	31722	0.0479	43042	1.113E-06	6.81
375	196.2	0.8073	58363	0.0474	67584	7.015E-07	6.23
333	217.3	0.8310	99306	0.0473	120706	3.921E-07	5.70
296	238.5	0.8546	179069	0.0467	223013	2.092E-07	5.22
	259.3	0.8777	322319				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE4A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.561
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.623
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.12

Test Parameters

Initial a (in)	0.883	Initial K	5.90
K-gradient	3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.228170	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
264.71	0.883	0.883	0.000	0.999
448.23	1.079	1.079	0.000	0.959

Comments

Date of test: 01-05-1998

Specimen Id. CE4A Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5
	264.7	0.8835	5				
270	280.7	0.9012	110465	0.0375	209195	1.794E-07	5.06
284	298.7	0.9210	209200	0.0472	183100	2.579E-07	5.49
301	323.9	0.9484	293565	0.0536	124894	4.295E-07	5.98
318	348.3	0.9747	334093	0.0464	62591	7.413E-07	6.53
338	367.2	0.9948	356156	0.0433	36611	1.183E-06	7.16
356	389.2	1.0180	370705	0.0452	27235	1.658E-06	7.76
376	410.3	1.0400	383392	0.0444	19711	2.254E-06	8.45
390	432.0	1.0624	390416	0.0289	9755	2.963E-06	8.92
	438.4	1.0689	393146				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE4B	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.561
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.623
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.12

Test Parameters

Initial a (in)	1.079	Initial K	12.60
K-gradient	-3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.219550	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
452.17	1.079	1.079	0.000	0.991
681.39	1.366	1.366	0.000	1.015

Comments

Date of test: 01-07-1998

Specimen Id. CE4B Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	453.9	1.0811	23				
376	455.5	1.0830	4619	0.0395	16882	2.340E-06	9.17
356	486.0	1.1206	16904	0.0591	21321	2.770E-06	8.82
307	503.4	1.1421	25940	0.0471	26979	1.746E-06	7.95
273	524.1	1.1677	43883	0.0550	54875	1.002E-06	7.32
241	547.7	1.1970	80814	0.0566	84170	6.723E-07	6.71
214	569.5	1.2243	128052	0.0493	143490	3.439E-07	6.18
187	587.1	1.2464	224304	0.0526	325195	1.618E-07	5.63
168	611.3	1.2769	453247	0.0556	529532	1.051E-07	5.22
147	631.2	1.3020	753836	0.0520	560671	9.280E-08	4.77
130	652.4	1.3289	1013918	0.0526	860338	6.113E-08	4.40
	672.5	1.3546	1614174				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE4C	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.561
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.623
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.20
Final a (in)	0.717	Kmax	11.12

Test Parameters

Initial a (in)	1.366	Initial K	5.00
K-gradient	3.50	Stress ratio (R)	0.20

K Coeff	PD Coeff	Analysis Codes		
	0.224500	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
680.85	1.367	1.367	0.000	1.001
918.21	1.625	1.625	0.000	0.981

Comments

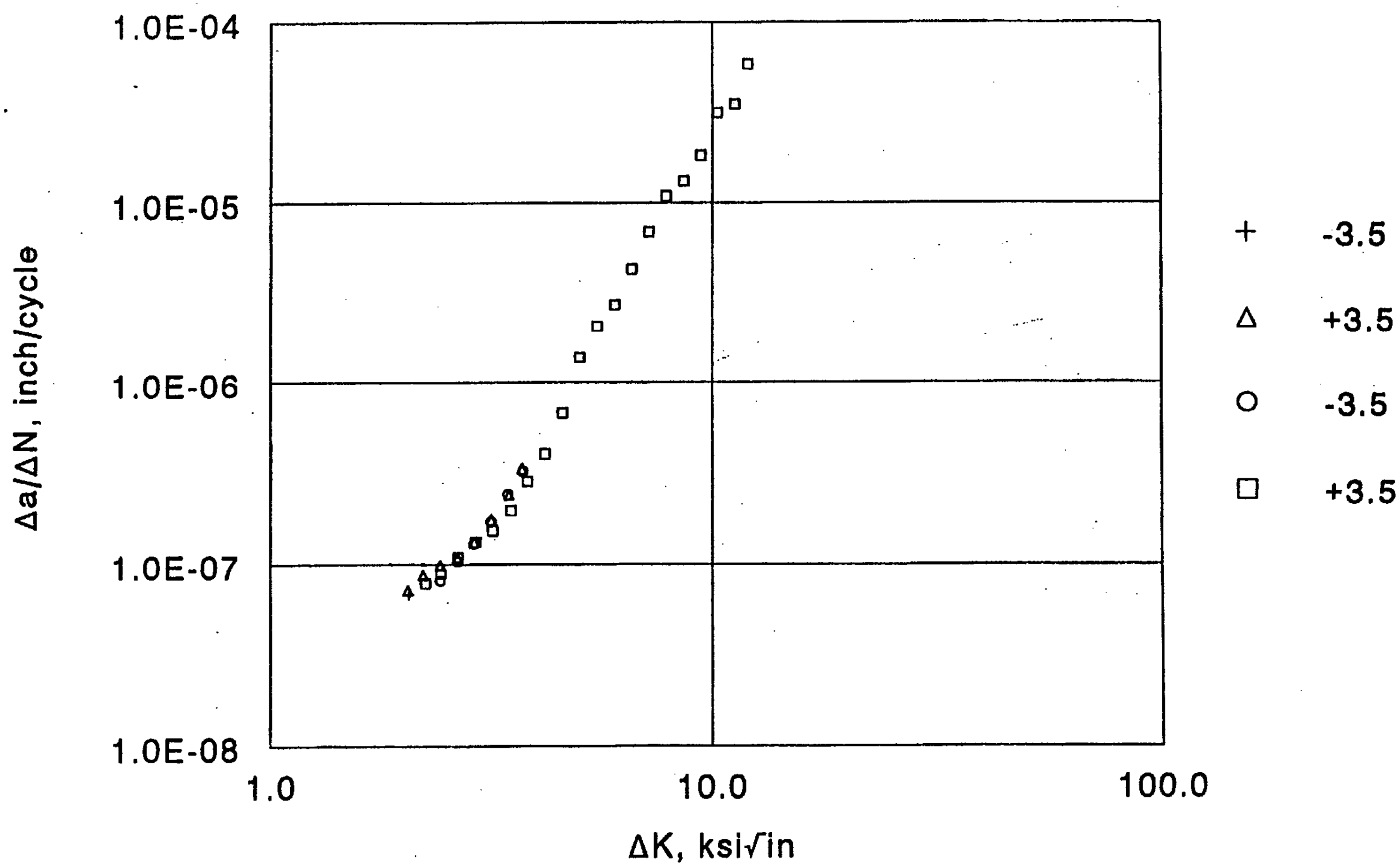
Date of test: 01-11-1998

Specimen Id. CE4C   Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	680.3	1.3659	21				
116	684.0	1.3701	198568	0.0366	588487	6.227E-08	4.27
120	713.2	1.4026	588508	0.0574	607488	9.452E-08	4.50
126	735.8	1.4275	806056	0.0479	316526	1.515E-07	4.98
132	756.7	1.4505	905034	0.0446	355765	1.255E-07	5.41
138	776.4	1.4721	1161821	0.0421	346490	1.214E-07	5.86
146	795.1	1.4926	1251524	0.0543	134882	4.022E-07	6.48
152	826.1	1.5264	1296703	0.0548	69480	7.887E-07	6.99
159	845.5	1.5474	1321004	0.0328	38631	8.481E-07	7.59
172	856.4	1.5591	1335334	0.0781	31993	2.442E-06	8.90
	918.2	1.6255	1352997				

Fairchild DTA 06-8520 CE5

2014-T65121 EXTR ECT SPEC. R=0.8



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE5	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.587
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.14

Test Parameters

Initial a (in)	0.717	Initial K	11.20
K-gradient	-3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.243010	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
92.02	0.717	0.717	0.000	0.998
134.33	0.762	0.762	0.000	0.968

Comments

Date of test: 01-07-1998

Specimen Id. CE5

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	92.0	0.7175	10				
542	108.1	0.7349	234398	0.0405	595311	6.797E-08	2.06
	129.9	0.7580	595320				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE5A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.587
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.14

Test Parameters

Initial a (in)	0.762	Initial K	9.50
K-gradient	3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.240980	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
134.38	0.762	0.762	0.000	0.999
314.70	0.977	0.977	0.000	1.003

Comments

Date of test: 01-09-1998

Specimen Id. CE5A Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	134.4	0.7625	76				
507	150.0	0.7809	297445	0.0436	611395	7.136E-08	2.05
533	171.2	0.8061	611470	0.0512	588225	8.710E-08	2.22
564	193.2	0.8322	885670	0.0512	520967	9.831E-08	2.42
597	214.4	0.8573	1132437	0.0500	459873	1.088E-07	2.65
631	235.3	0.8822	1345543	0.0509	382641	1.331E-07	2.89
667	257.2	0.9083	1515078	0.0515	293322	1.756E-07	3.16
706	278.6	0.9337	1638865	0.0508	210509	2.415E-07	3.45
737	299.9	0.9591	1725587	0.0389	116000	3.357E-07	3.70
	311.2	0.9726	1754865				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE5B	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.587
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.14

Test Parameters

Initial a (in)	0.977	Initial K	20.00
K-gradient	-3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.240980	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
314.70	0.977	0.977	0.000	1.003
473.40	1.167	1.168	0.000	1.008

Comments

Date of test: 01-11-1998

Specimen Id. CE5B Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	315.5	0.9777	773				
696	332.0	0.9974	49157	0.0450	138597	3.248E-07	3.71
626	353.1	1.0228	139370	0.0503	207592	2.425E-07	3.44
554	374.0	1.0478	256748	0.0504	293562	1.718E-07	3.15
491	395.1	1.0732	432932	0.0518	398702	1.299E-07	2.89
435	417.1	1.0996	655450	0.0513	495089	1.036E-07	2.65
384	437.7	1.1245	928021	0.0510	630304	8.097E-08	2.42
	459.4	1.1506	1285755				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE5C	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.587
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.614
Width	2.506	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.14

Test Parameters

Initial a (in)	1.168	Initial K	10.40
K-gradient	3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.242760	KREP	1	0
	0.471310			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
473.46	1.168	1.168	-.001	1.001
686.94	1.430	1.433	0.003	1.013
799.51	1.571	1.569	-.002	1.019

Comments

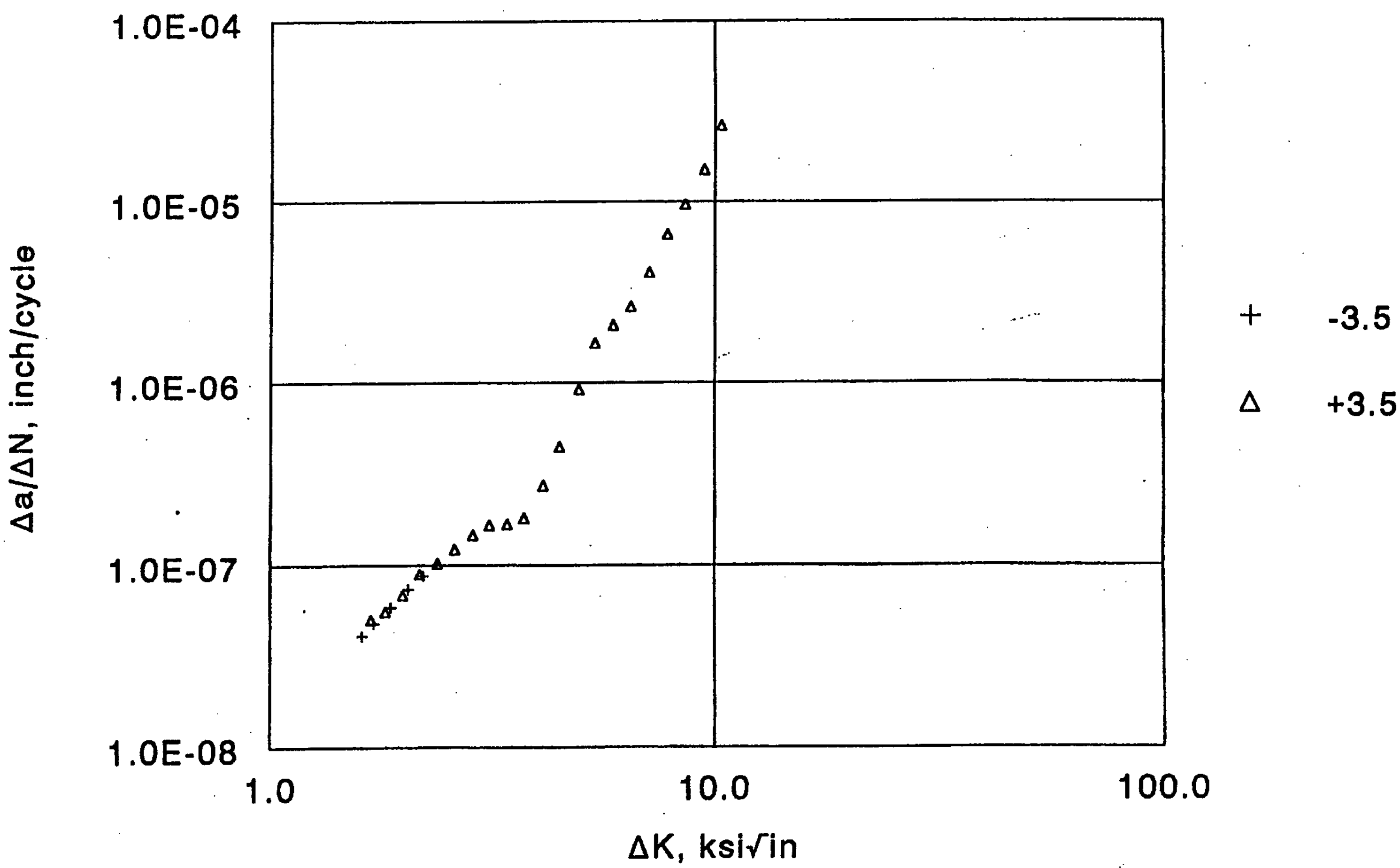
Date of test: 01-13-1998

Specimen Id. CE5C Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	473.5	1.1681	11				
326	489.7	1.1879	255607	0.0450	574805	7.835E-08	2.25
341	510.5	1.2131	574816	0.0515	581824	8.847E-08	2.43
359	531.9	1.2393	837431	0.0526	482024	1.092E-07	2.66
379	553.6	1.2658	1056840	0.0538	406754	1.324E-07	2.92
398	575.9	1.2932	1244185	0.0518	338043	1.534E-07	3.18
420	595.8	1.3176	1394882	0.0519	263265	1.973E-07	3.50
440	618.1	1.3451	1507450	0.0529	184323	2.868E-07	3.81
463	638.7	1.3705	1579205	0.0502	124673	4.026E-07	4.16
486	658.7	1.3953	1632122	0.0536	79355	6.755E-07	4.57
510	681.9	1.4241	1658560	0.0561	40264	1.393E-06	4.99
535	703.9	1.4514	1672387	0.0521	24885	2.093E-06	5.47
561	723.8	1.4762	1683445	0.0509	18528	2.745E-06	6.00
587	744.7	1.5023	1690914	0.0533	12303	4.335E-06	6.55
614	766.4	1.5295	1695748	0.0545	7857	6.936E-06	7.18
642	788.2	1.5568	1698771	0.0522	4802	1.087E-05	7.85
670	808.4	1.5817	1700549	0.0507	3856	1.315E-05	8.61
699	829.8	1.6075	1702627	0.0520	2847	1.826E-05	9.41
728	851.6	1.6337	1703396	0.0507	1595	3.175E-05	10.28
757	871.9	1.6581	1704222	0.0495	1402	3.530E-05	11.24
782	892.7	1.6832	1704798	0.0425	721	5.889E-05	12.10
	907.1	1.7006	1704944				

Fairchild DTA 06-8520 CE6

2014-T65121 EXTR ECT SPEC. R=0.8



AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE6	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.599
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.620
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.16

Test Parameters

Initial a (in)	0.768	Initial K	12.00
K-gradient	-3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.247340	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
126.52	0.768	0.768	0.000	1.000
238.54	0.897	0.897	0.000	0.986

Comments

Date of test: 01-26-1998

Specimen Id. CE6 Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	126.5	0.7685	5				
544	142.5	0.7870	204076	0.0433	495287	8.735E-08	2.22
490	163.9	0.8118	495291	0.0492	669261	7.358E-08	2.05
435	185.2	0.8362	873337	0.0488	834159	5.849E-08	1.88
386	206.5	0.8606	1329450	0.0480	1012256	4.744E-08	1.72
355	227.3	0.8843	1885593	0.0330	815777	4.050E-08	1.62
	235.5	0.8936	2145227				

AUTOMATED FATIGUE CRACK GROWTH RATE ANALYSIS

Specimen Id.	CE6A	Geometry	ECT
Contract #	06-8520	Orientation	LT
Material	2024-T6511	Yield (ksi)	60.7
Temperature (F)	74	Initial A0 (PD)	0.599
Environment	LA	Initial PD	%1000.00

Specimen Dimensions (in)

Thickness	0.116	Notch depth	0.620
Width	2.503	Gage length	0.000
Height	0.000		

Precrack Parameters

Pmax (lbs)	600.0	Stress ratio (R)	0.80
Final a (in)	0.717	Kmax	11.16

Test Parameters

Initial a (in)	0.897	Initial K	7.80
K-gradient	3.50	Stress ratio (R)	0.80

K Coeff	PD Coeff	Analysis Codes		
	0.247340	KREP	1	0
	0.471870			
	0.000000			
	0.000000			
	0.000000			
	0.000000			

Visual Observations

PD	Crack (PD)	Crack (visual)	Error	PDAF
238.51	0.896	0.897	0.001	0.981
466.43	1.179	1.172	-.007	1.015
635.18	1.400	1.405	0.005	1.041

Comments

Date of test: 01-30-1998

Specimen Id. CE6A Page 1

Pmax (lbs)	PD (1E-6)	a (in)	N (X1)	da (in)	dN (X1)	da/dN (in/cyc)	dK (ksi[in]^.5)
	238.5	0.8956	6				
353	254.0	0.9142	410374	0.0441	886120	4.973E-08	1.69
370	275.0	0.9396	886126	0.0506	912919	5.540E-08	1.83
391	295.6	0.9647	1323292	0.0519	757716	6.855E-08	2.00
413	317.5	0.9916	1643841	0.0529	593149	8.924E-08	2.18
437	338.7	1.0177	1916441	0.0529	517766	1.023E-07	2.39
461	360.3	1.0445	2161608	0.0524	430368	1.219E-07	2.61
487	380.8	1.0701	2346809	0.0534	364743	1.464E-07	2.86
513	403.0	1.0979	2526351	0.0529	319007	1.659E-07	3.12
542	422.9	1.1230	2665816	0.0521	311023	1.675E-07	3.42
570	444.1	1.1500	2837374	0.0541	300463	1.801E-07	3.73
604	465.4	1.1772	2966279	0.0591	217838	2.715E-07	4.12
635	490.2	1.2091	3055212	0.0562	126822	4.431E-07	4.49
672	509.0	1.2334	3093100	0.0527	57272	9.202E-07	4.96
704	530.9	1.2618	3112483	0.0541	32740	1.653E-06	5.39
743	550.5	1.2875	3125840	0.0548	26417	2.075E-06	5.93
780	572.6	1.3167	3138900	0.0574	21967	2.613E-06	6.48
821	594.0	1.3449	3147807	0.0571	14145	4.037E-06	7.14
863	615.7	1.3738	3153045	0.0569	8651	6.581E-06	7.83
906	636.8	1.4018	3156457	0.0534	5539	9.645E-06	8.58
954	657.4	1.4272	3158584	0.0550	3643	1.511E-05	9.47
1000	681.6	1.4569	3160100	0.0549	2073	2.650E-05	10.33
	702.1	1.4821	3160658				

APPENDIX G2

Spectrum Crack Growth Tests

Data: Simple Coupon Geometry Results
Complex Coupon Geometry Results

Data: Simple Coupon Geometry Results

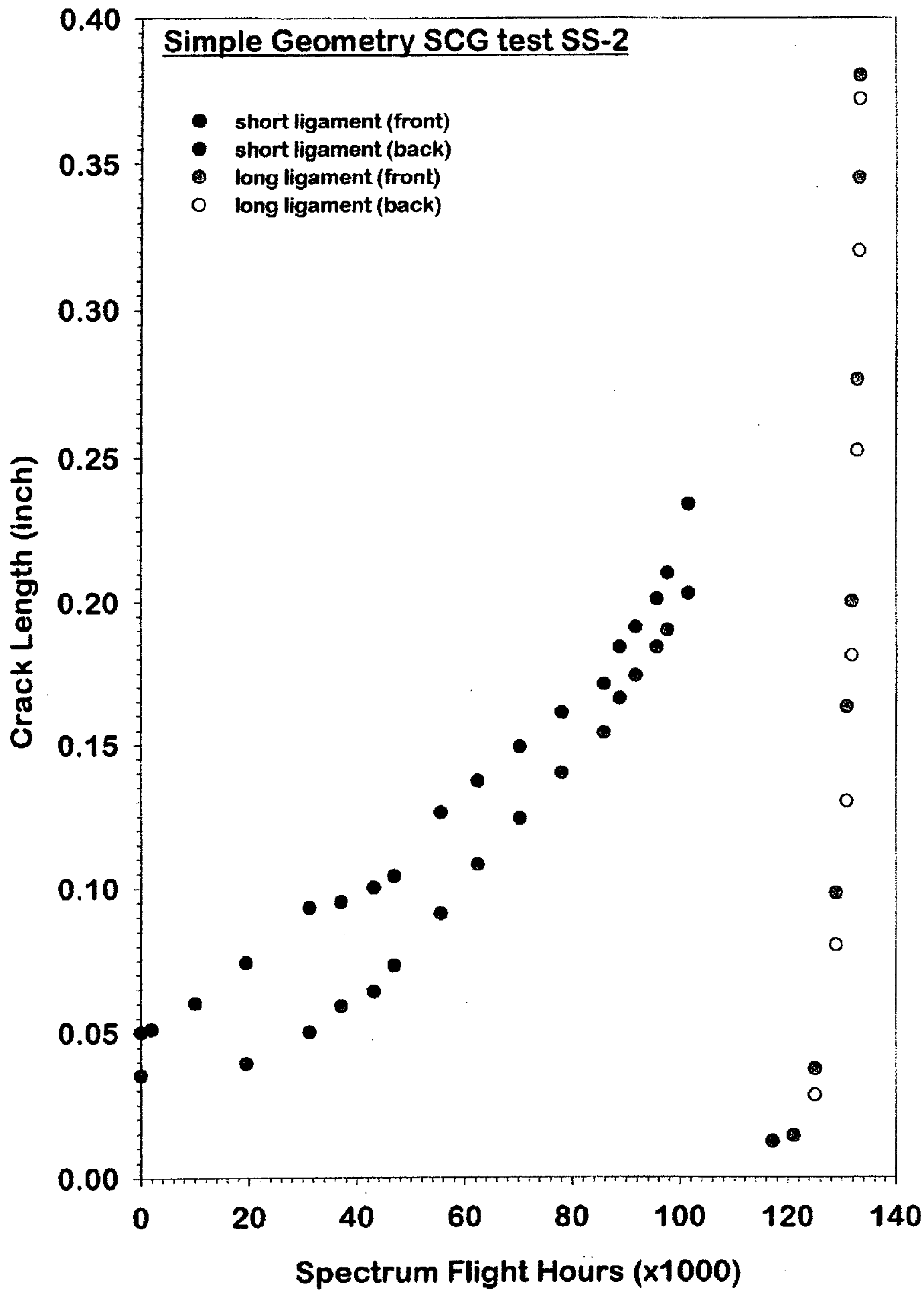
- Spectrum Crack Growth Plots (a vs SFH)

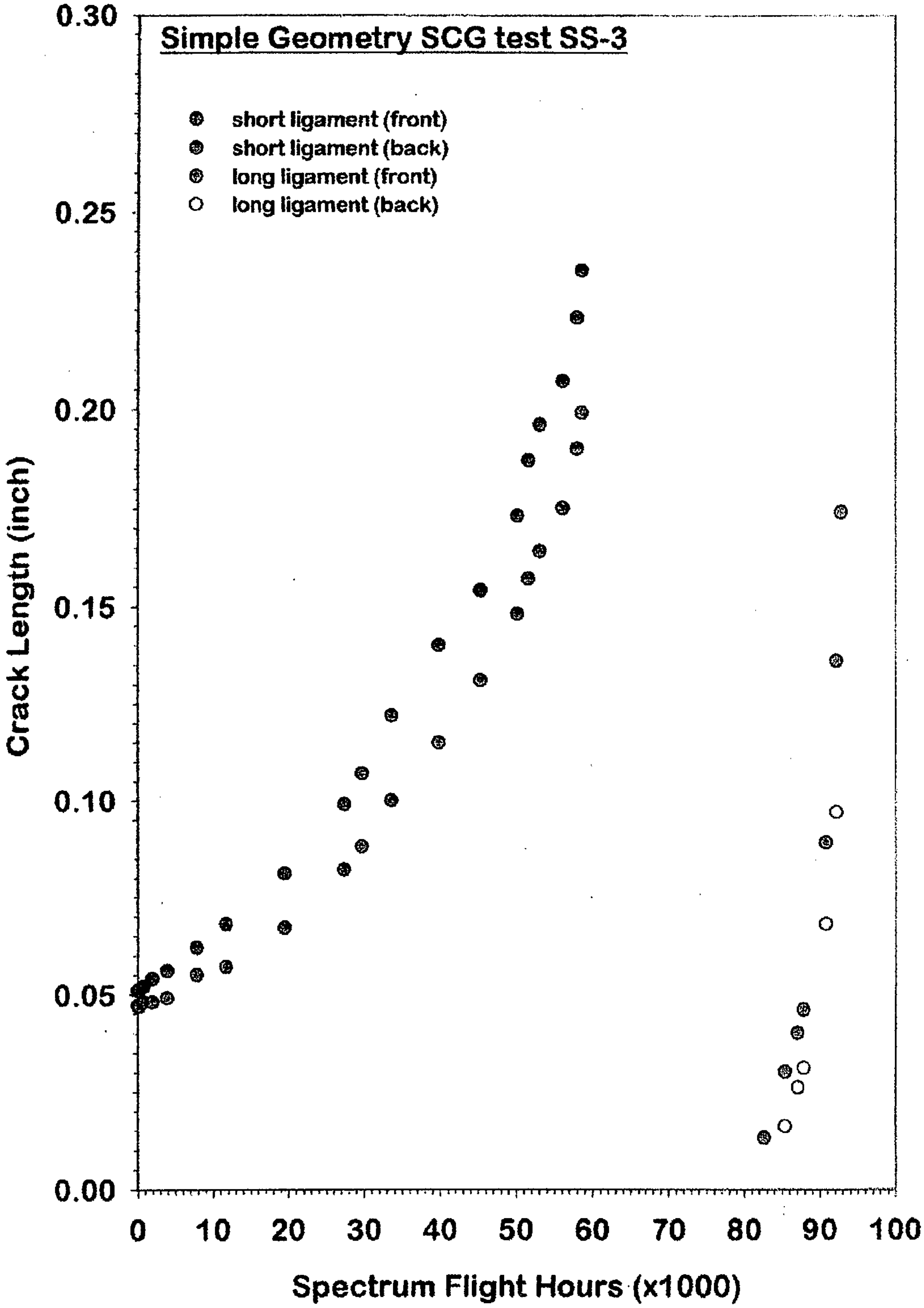
Complex Coupon Geometry Results

- Spectrum Crack Growth Plots (a vs SFH)
- Analysis of Non-Visual Crack Length Measurements
- Graphical Compliance and Strain Data
- Analyzed Compliance Data

Simple Coupon Geometry Tests

2 tests:	SS-2
	SS-3

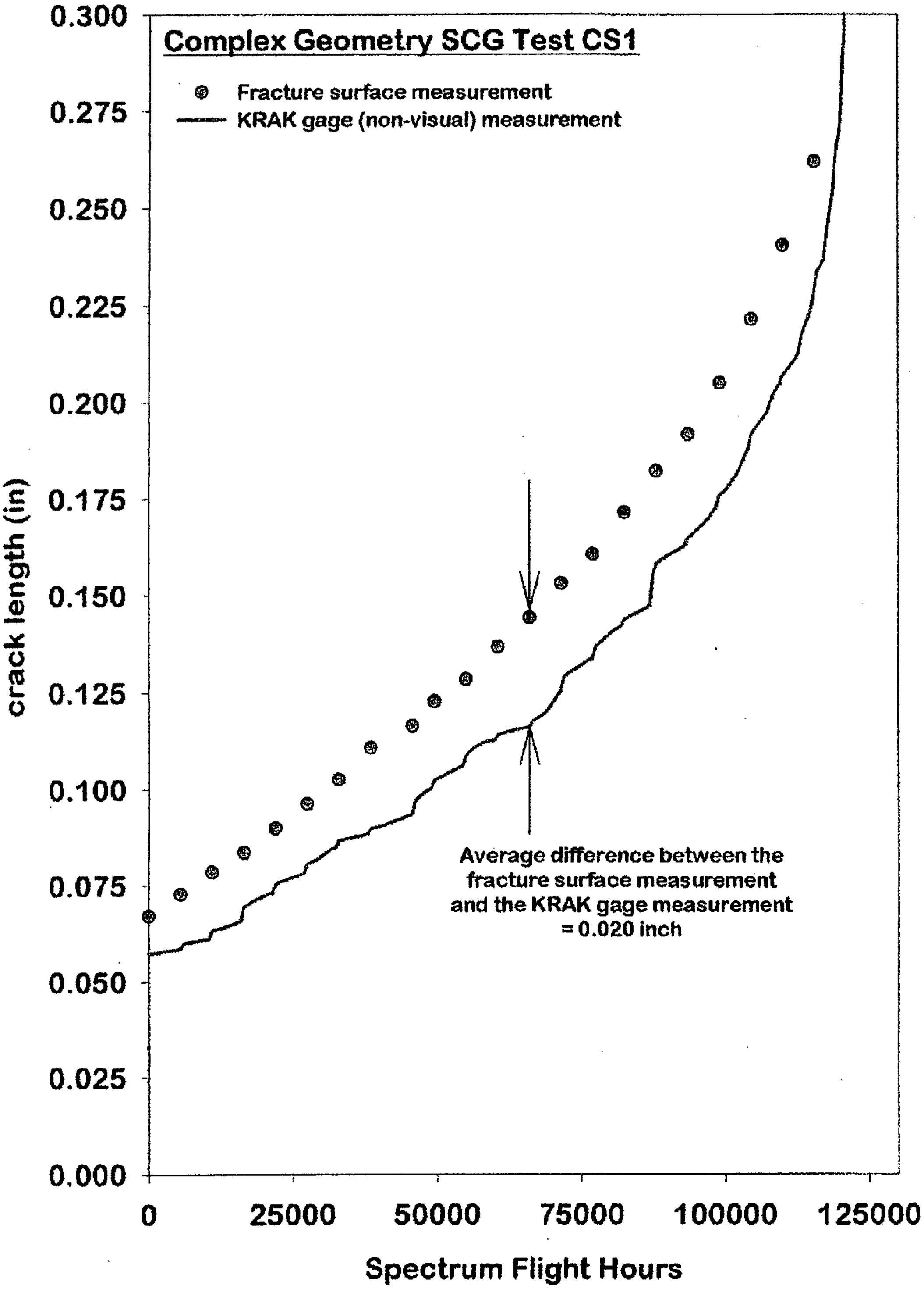

Simple Geometry SCG test SS-2
short ligament (front)
short ligament (back)
long ligament (front)
long ligament (back)
Crack Length (inch)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
20
40
60
80
100
120
140
Spectrum Flight Hours (x1000)



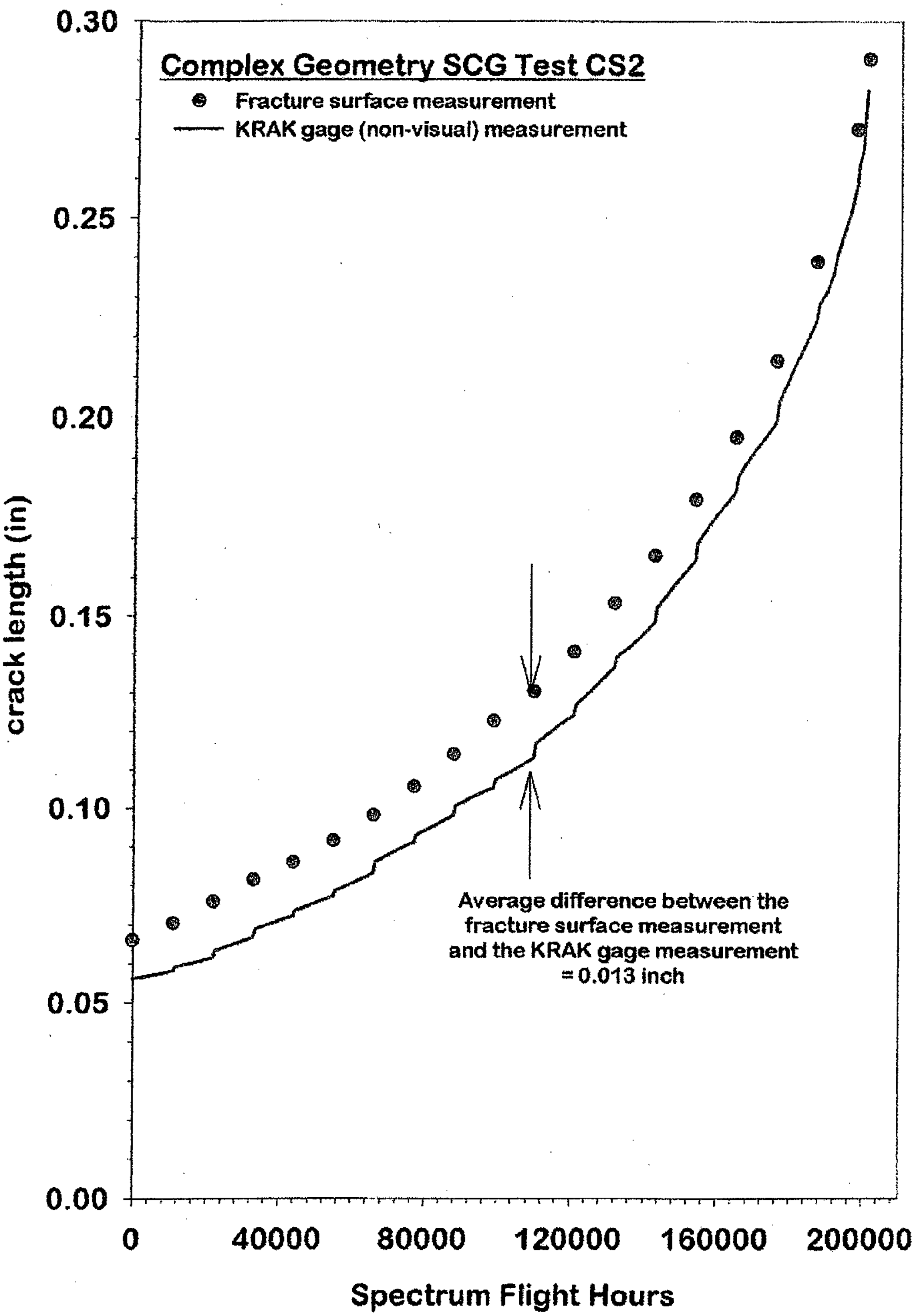
Simple Geometry SCG test SS-3
short ligament (front)
short ligament (back)
long ligament (front)
long ligament (back)
Crack Length (inch)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
10
20
30
40
50
60
70
80
90
100
Spectrum Flight Hours (x1000)

Complex Coupon Geometry Tests

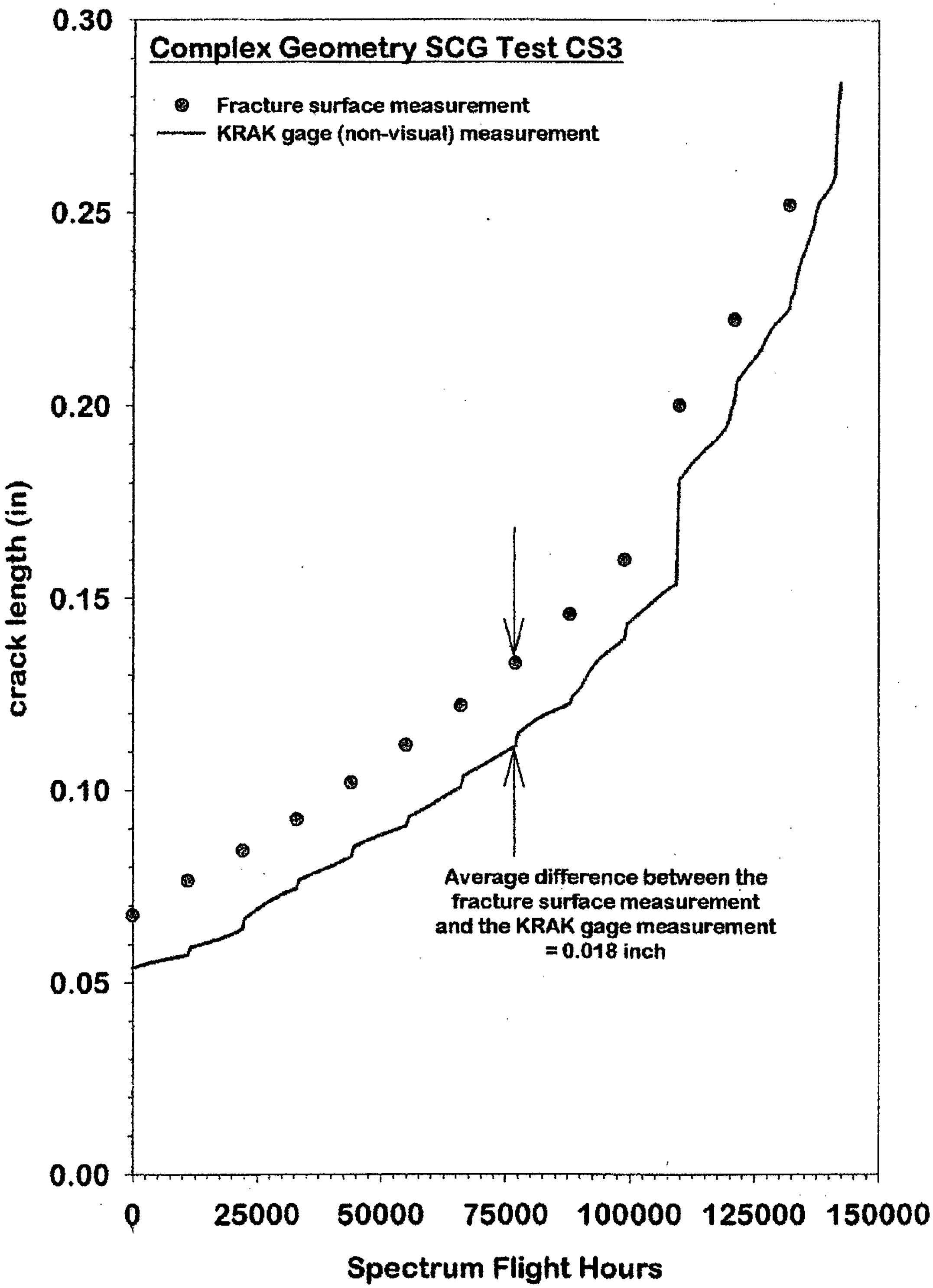
3 tests: CS-1 to –3



Complex Geometry SCG Test CS1
Fracture surface measurement
KRAK gage (non-visual) measurement
Average difference between the fracture surface measurement and the KRAK gage measurement = 0.020 inch
crack length (in)
0.300
0.275
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0
25000
50000
75000
100000
125000
Spectrum Flight Hours



Complex Geometry SCG Test CS2
Fracture surface measurement
KRAK gage (non-visual) measurement
Average difference between the fracture surface measurement and the KRAK gage measurement = 0.013 inch
crack length (in)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
0
40000
80000
120000
160000
200000
Spectrum Flight Hours



Complex Geometry SCG Test CS3
Fracture surface measurement
KRAK gage (non-visual) measurement
Average difference between the
fracture surface measurement
and the KRAK gage measurement
= 0.018 inch
0.30
0.25
0.20
0.15
0.10
0.05
0.00
crack length (in)
0
25000
50000
75000
100000
125000
150000
Spectrum Flight Hours

Analysis of Non-Visual Crack Length Measurements

Due to the unusually large difference found between the KRAK gage and markerband measurements, an investigation into possible causes for this discrepancy was undertaken. The KRAK gage position relative to the fastener hole was measured and the resulting offset added to the non-visual crack length measurements

Balancing or zeroing of all KRAK gages was performed after the complex joint had been assembled but prior to any applied loading cycles. Fractomat output was checked by performing a controlled crack growth experiment using a KRAK gage and two Fractomats (one of which was the Fractomat use for this project). Both Fractomats were zeroed using the gage, and then the KRAK gage was cut incrementally using a scalpel, with indicated voltage output measured for both Fractomats. Only an average difference of 0.001-inch was measured between the two Fractomats. Therefore the Fractomat was not considered a contributor to the crack length offsets found.

Upon further investigation of the procedure used to attach the gages to the test section of the complex joint, it was found that on two of the three test coupons the front of the foil gage was trimmed back from the fastener hole. A comparison of an original gage and that found on the test coupon CS1 is shown in Figure B.1. Clearly there is a difference in the initial portion of the KRAK gage. For tests CS1 and CS3 the amount of foil removed on the mid-section was measured as 0.013 inch and 0.005 inch, respectively.

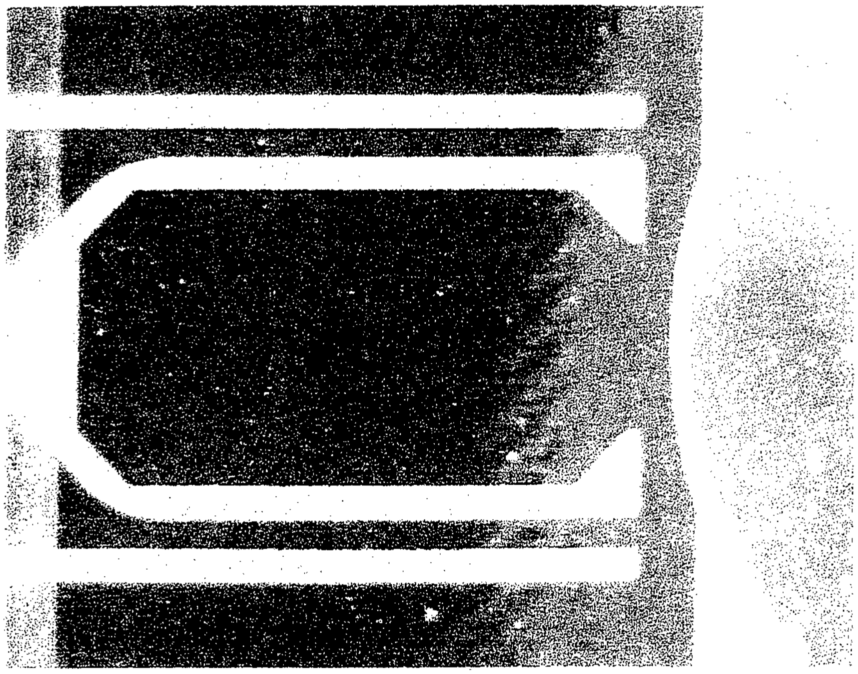
However, damage or cutting of the foil gage could result in incorrect crack lengths, when using the assigned calibration coefficients for this gage. A controlled experiment found that after trimming approximately 0.012 inch of foil from the KRAK gage, an average error of approximately 0.010 inch was found between the physical crack lengths and those calculated using the calibration coefficients, as shown in Figure B.2. All procedures mirrored those used in the complex geometry tests. When the crack length error in the controlled experiment is compared with the error obtained in the complex tests (Figure B.3), it is apparent that trimming the gages does not account for the total error observed. Also the gage on coupon CS2 was not trimmed and an error was still recorded.

It is also possible for the crack in the gage to lag behind the physical crack on the specimen if the glue line between the KRAK gage and the specimen is larger than normal, for example, not enough clamping force is used during attachment of the gages. This also relates to the type of backing used on the KRAK gage. The backing used for the complex geometry test was an epoxy-phenolic with fiberglass reinforcement. In hindsight it may have been advisable to use the –CE (or cast epoxy) backing. This backing is a very thin and brittle cast epoxy with no reinforcement, and is used for crack growth testing requiring utmost response and sensitivity such as in near-threshold testing or possibly when using benign civil aircraft spectra. However, due to it's inherent fragility it was decided against using the –CE backing.

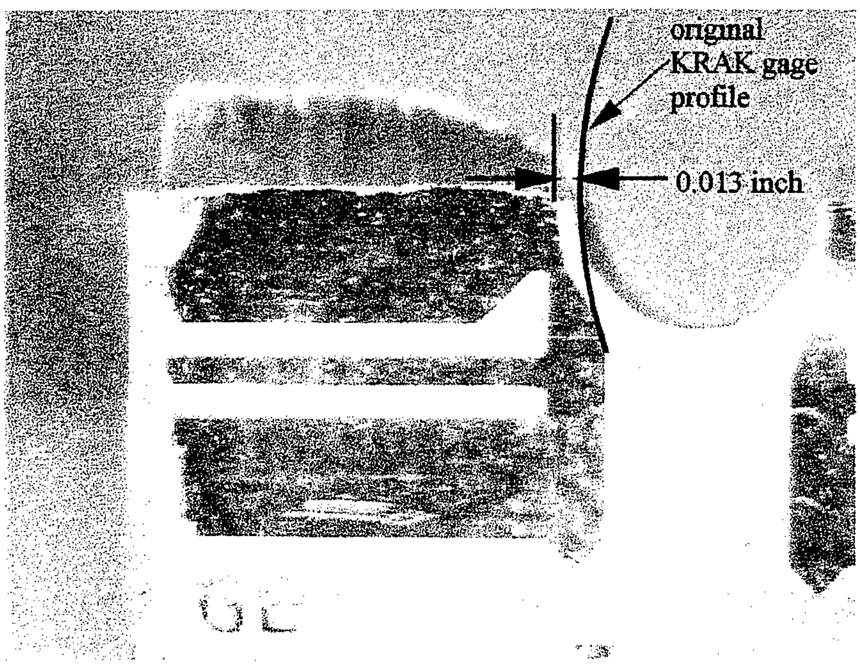
One final point with regard to the attachment method used in the complex geometry testing, is that a thin layer of teflon tape was placed between the extension tab and the KRAK gage, so that the gage was only attached to the test section and not the extension tab. This could possibly have wedged the gage away from the test section, resulting in a thicker glue line being applied. This may then have resulted in a crack length lag between the non-visual and physical crack length during spectrum testing.

In conclusion, the differences found between the non-visual (KRAK gage) and visual (markerband) crack length measurements could be explained in terms of the following:

- For tests CS1 and CS3, cutting of the foil gage resulted in incorrect crack length calculations using the supplied calibration equation.
- It is possible that a combination of glue line thickness and KRAK gage backing material decreased the sensitivity of the KRAK gage to measure the physical crack length accurately.



(a)



(b)

Figure B.1. Comparison of KRAK gages KG-BH5616-X08 (a) unused and (b) test CS1.

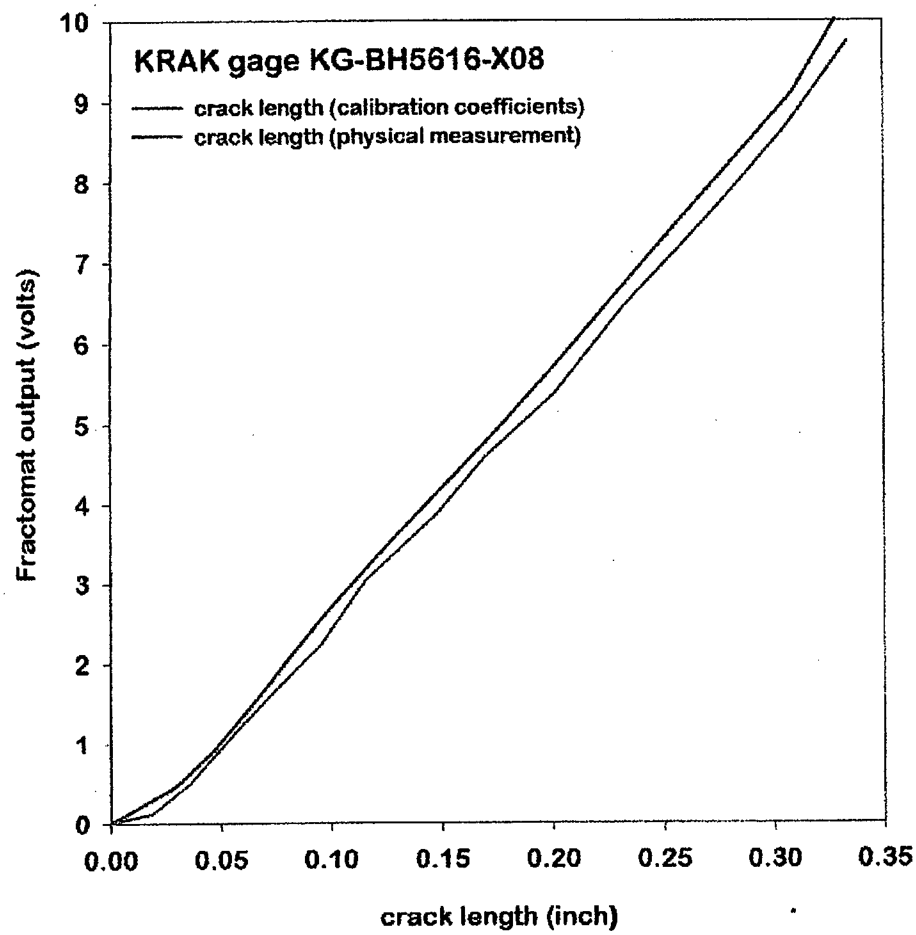


Figure B.2 Comparison of calculated and physically measured crack length for the controlled KRAK gage experiment

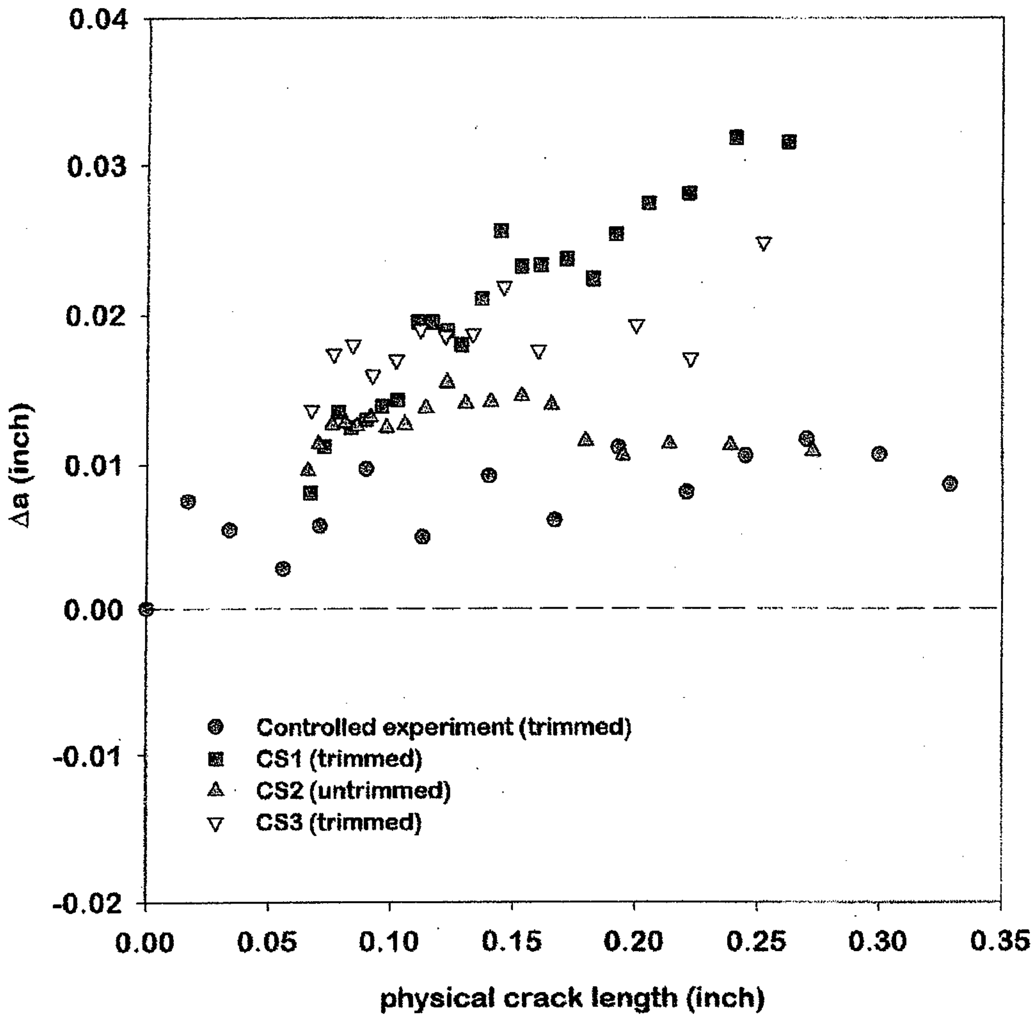
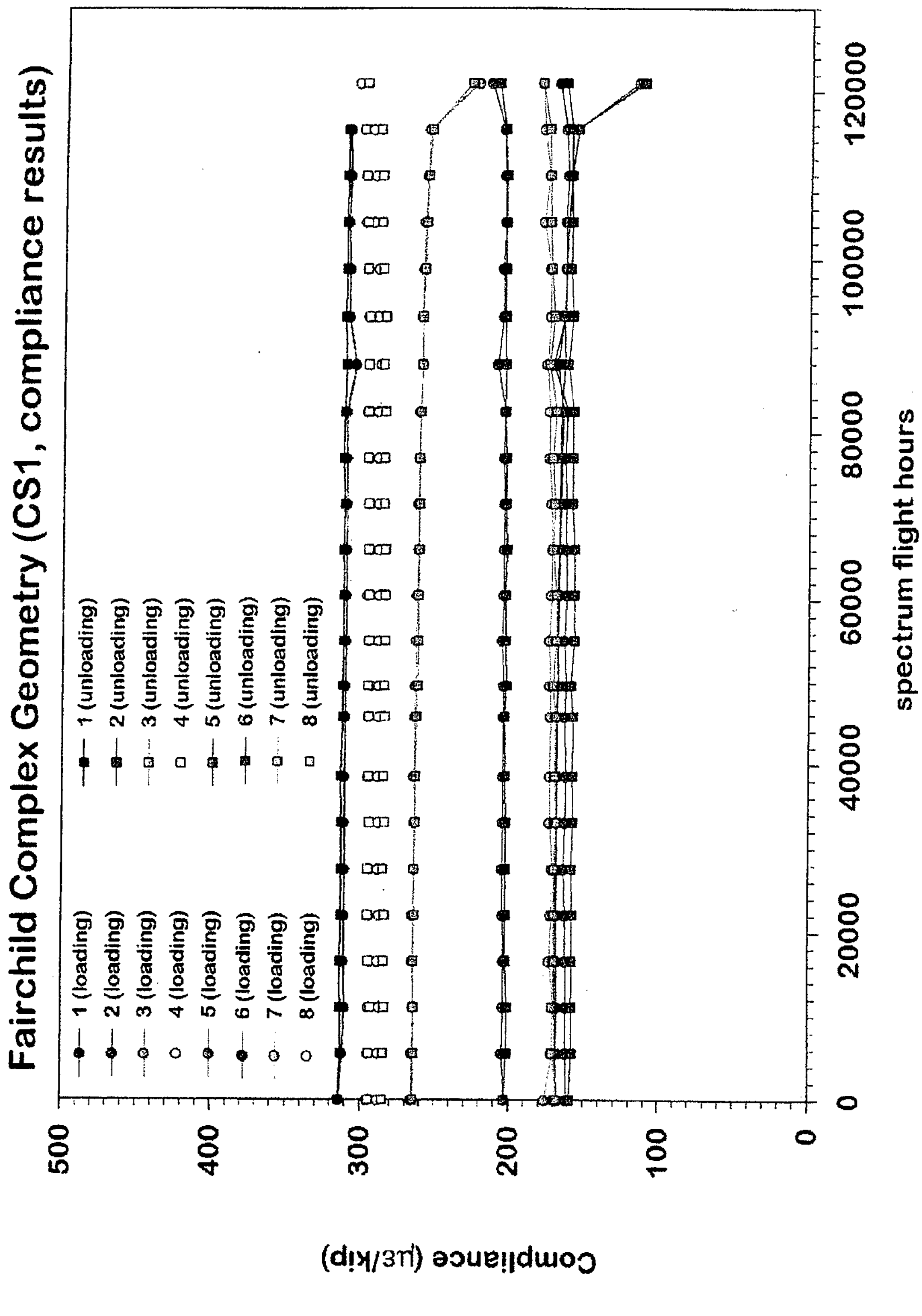
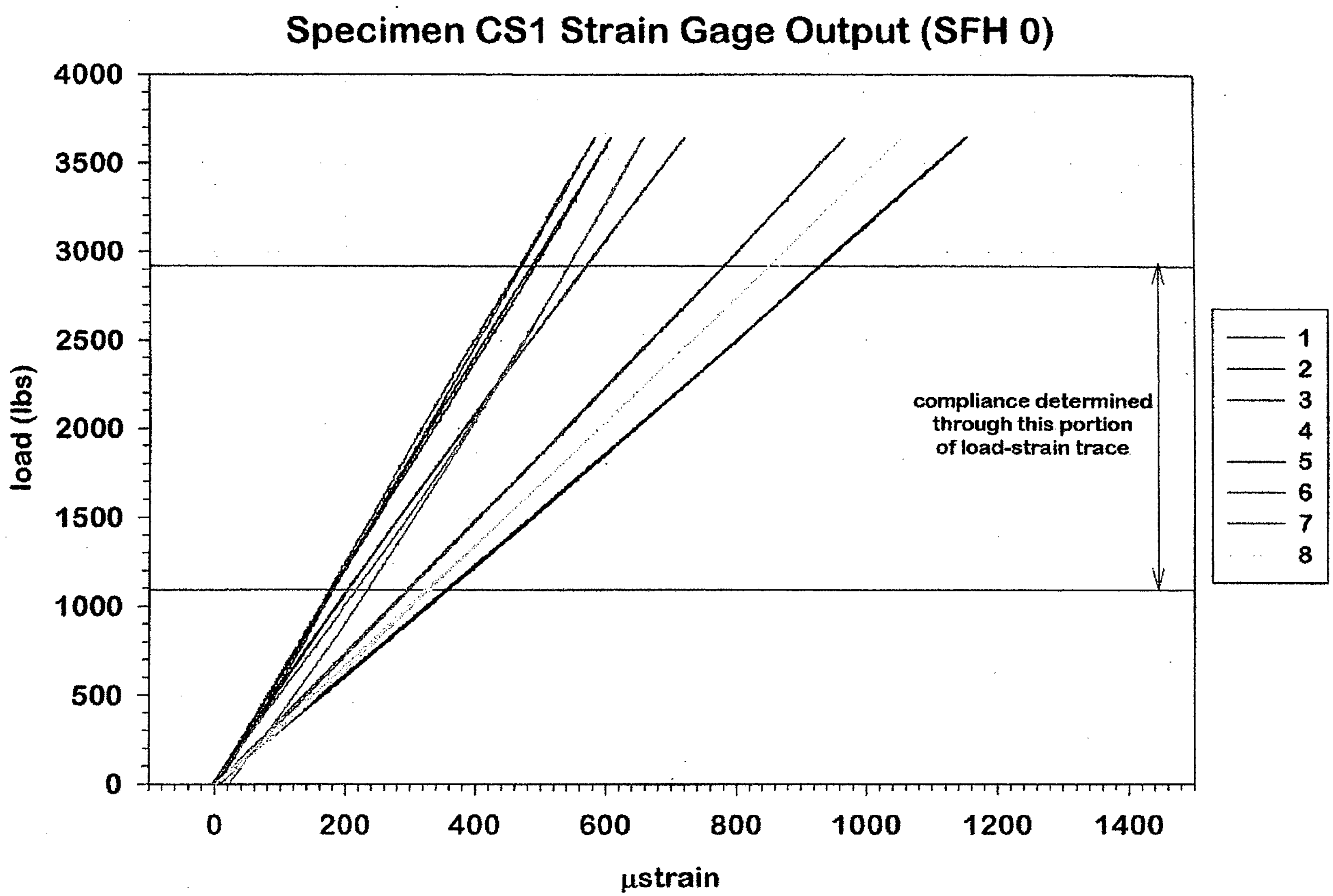


Figure B.3 Comparison of crack length error between markerbands and KRAK gage

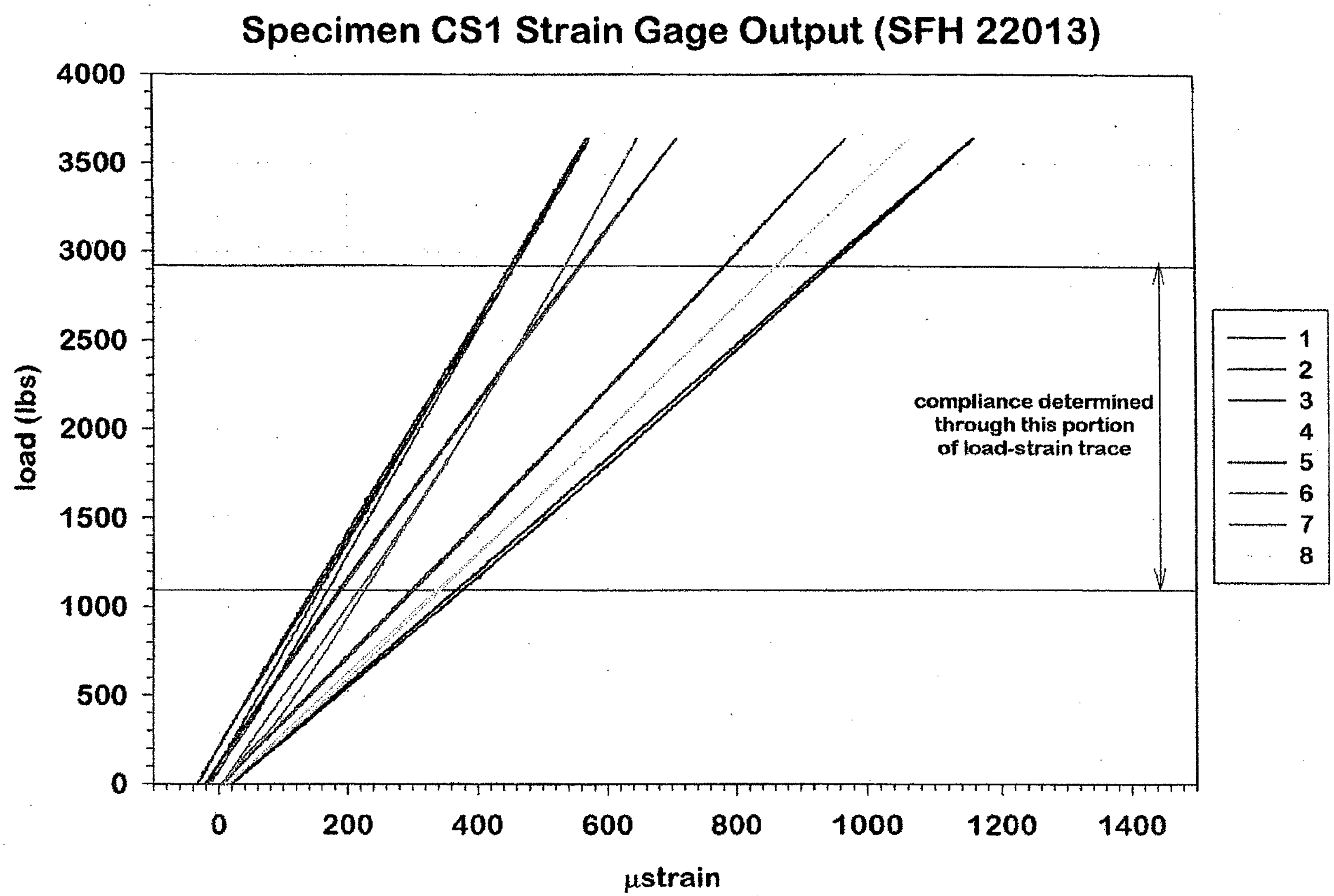
Graphical Compliance and Strain Data



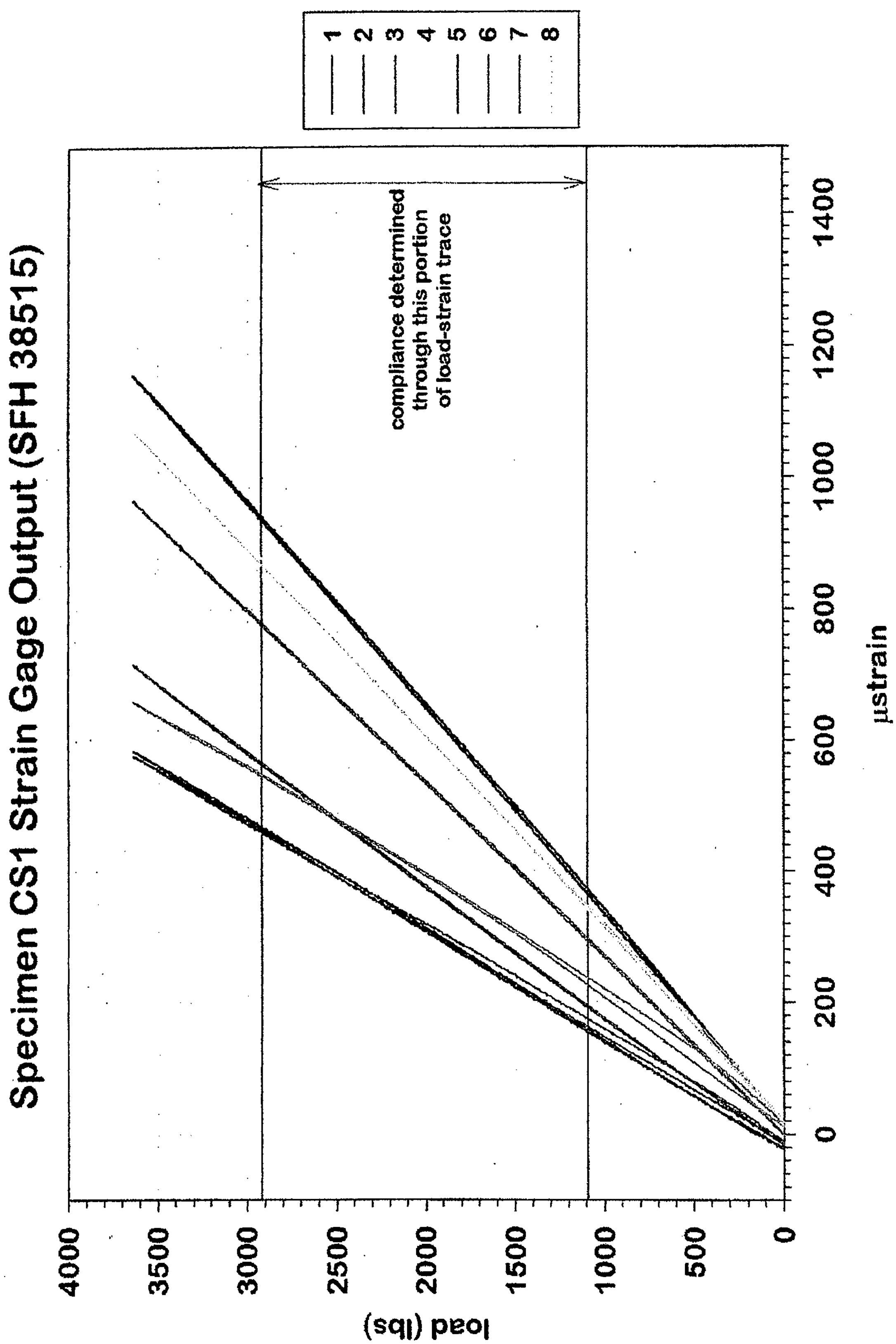
Fairchild Complex Geometry (CS1, compliance results)
1 (loading)
2 (loading)
3 (loading)
4 (loading)
5 (loading)
6 (loading)
7 (loading)
8 (loading)
1 (unloading)
2 (unloading)
3 (unloading)
4 (unloading)
5 (unloading)
6 (unloading)
7 (unloading)
8 (unloading)
500
400
300
200
100
0
Compliance (με/kip)
0
20000
40000
60000
80000
100000
120000
spectrum flight hours

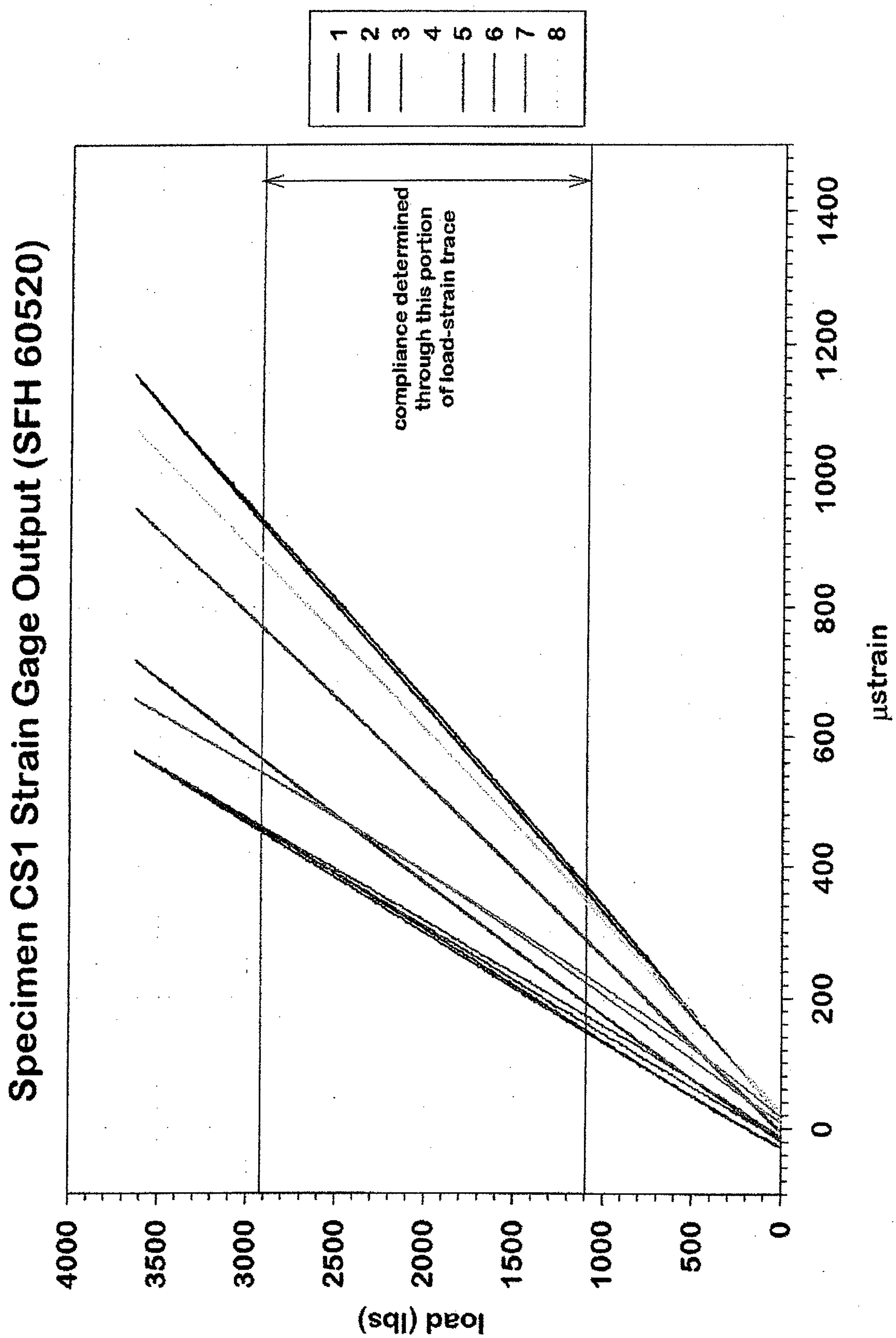


Specimen CS1 Strain Gage Output (SFH 0)
load (lbs)
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
μstrain
compliance determined through this portion of load-strain trace
1
2
3
4
5
6
7
8

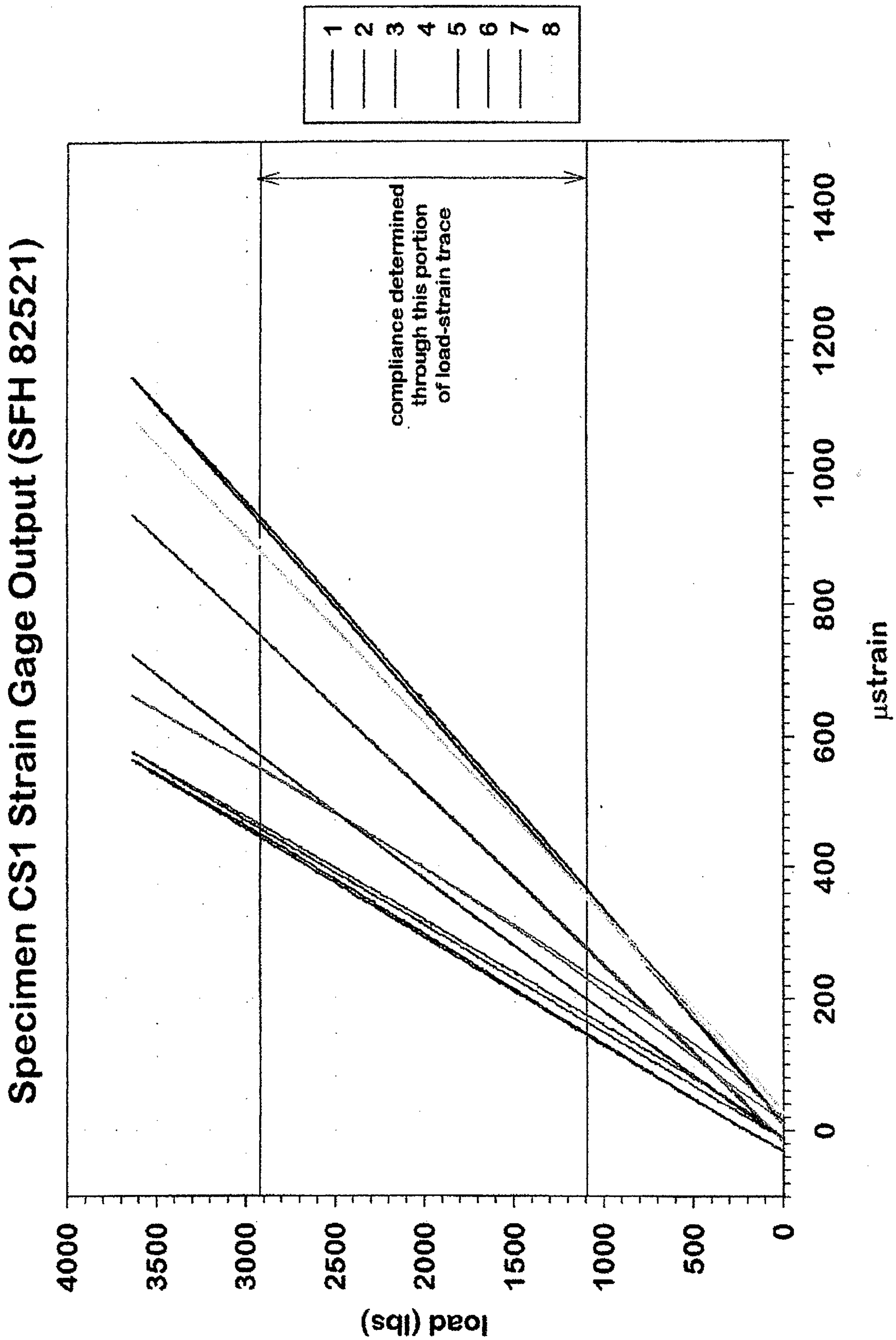


Specimen CS1 Strain Gage Output (SFH 22013)
load (lbs)
4000
3500
3000
2500
2000
1500
1000
500
0
-200
0
200
400
600
800
1000
1200
1400
μstrain
compliance determined
through this portion
of load-strain trace
1
2
3
4
5
6
7
8

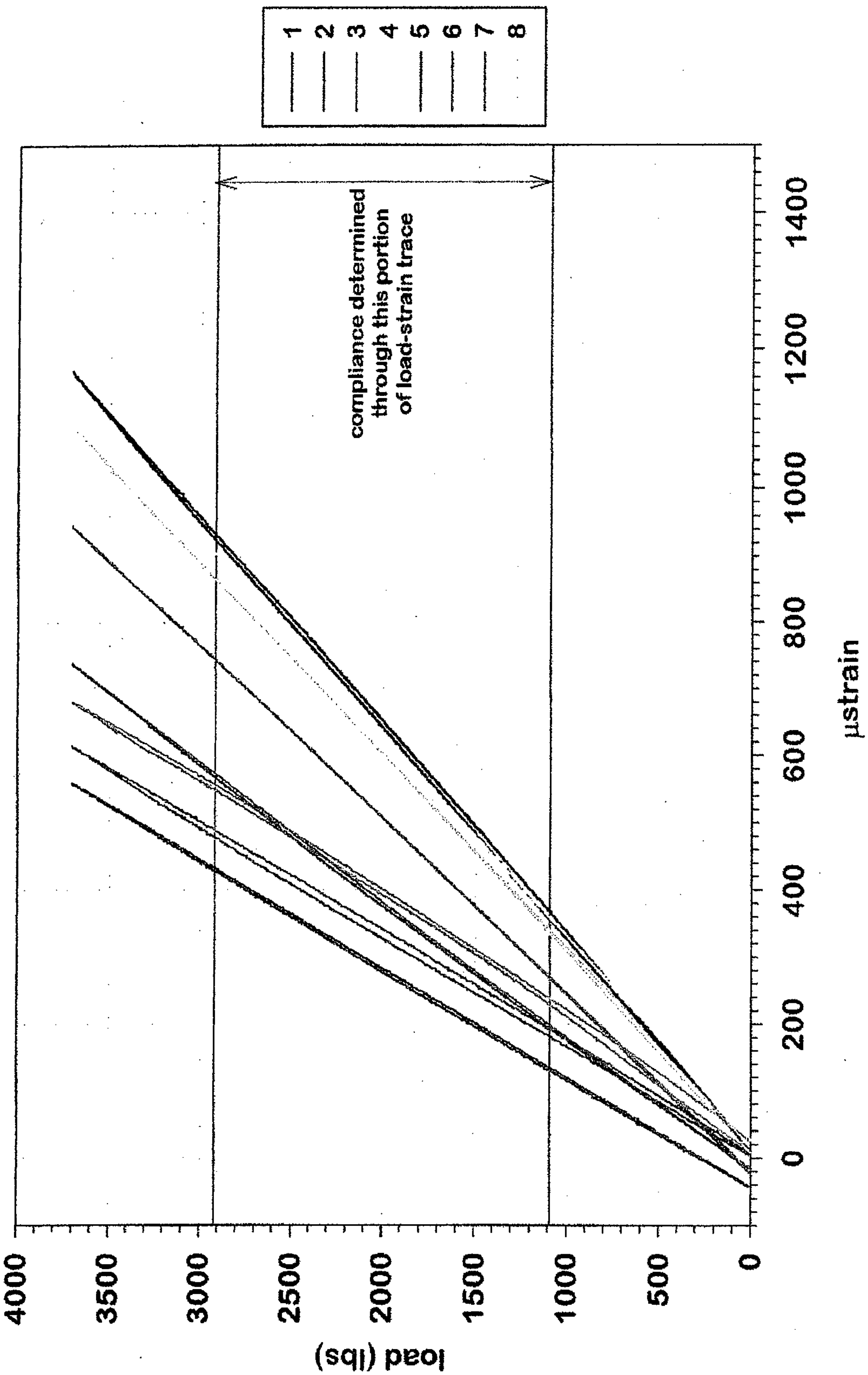

Specimen CS1 Strain Gage Output (SFH 38515)
load (lbs)
µstrain
compliance determined
through this portion
of load-strain trace
1
2
3
4
5
6
7
8
0
500
1000
1500
2000
2500
3000
3500
4000
200
400
600
800
1000
1200
1400

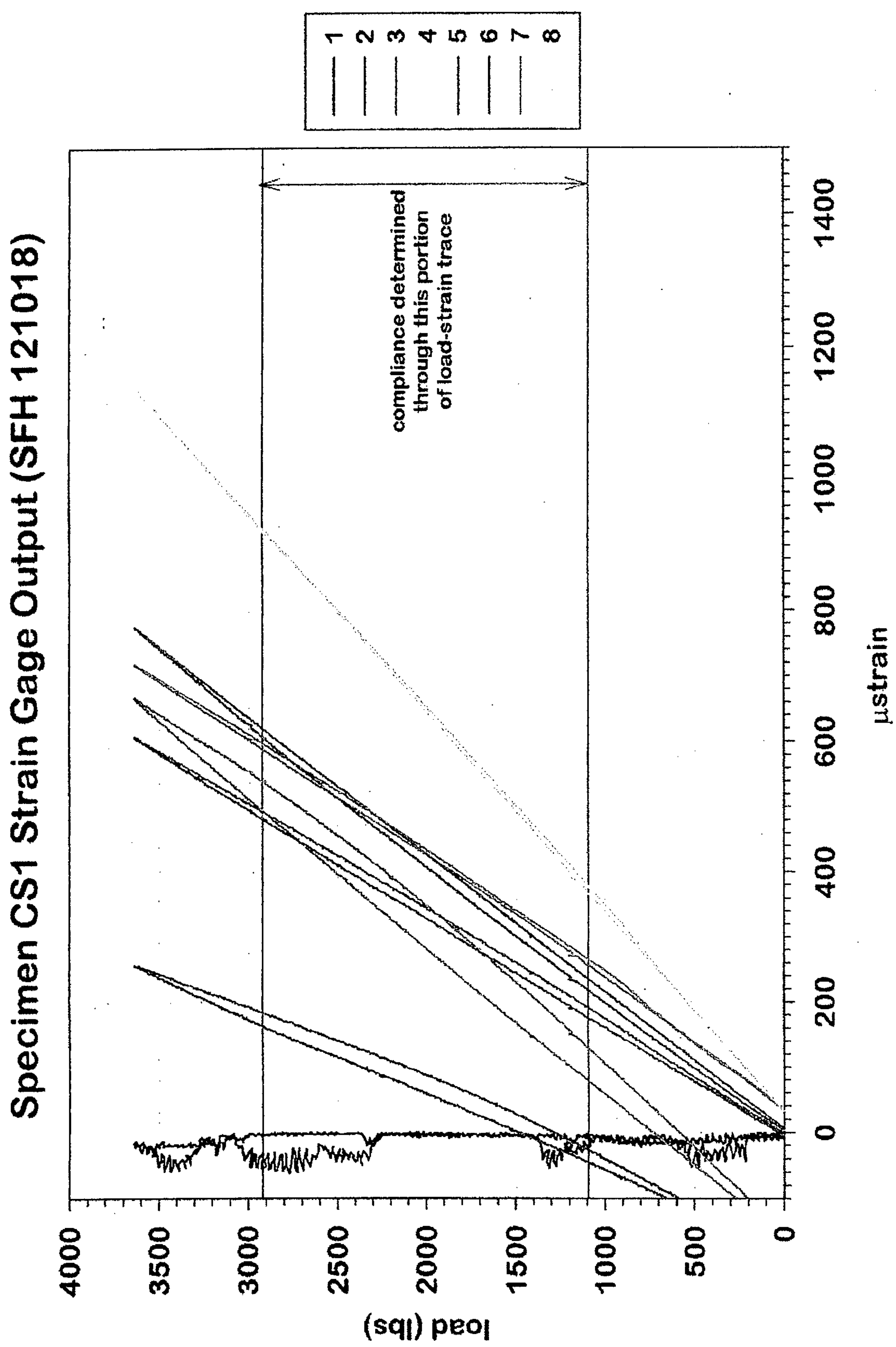


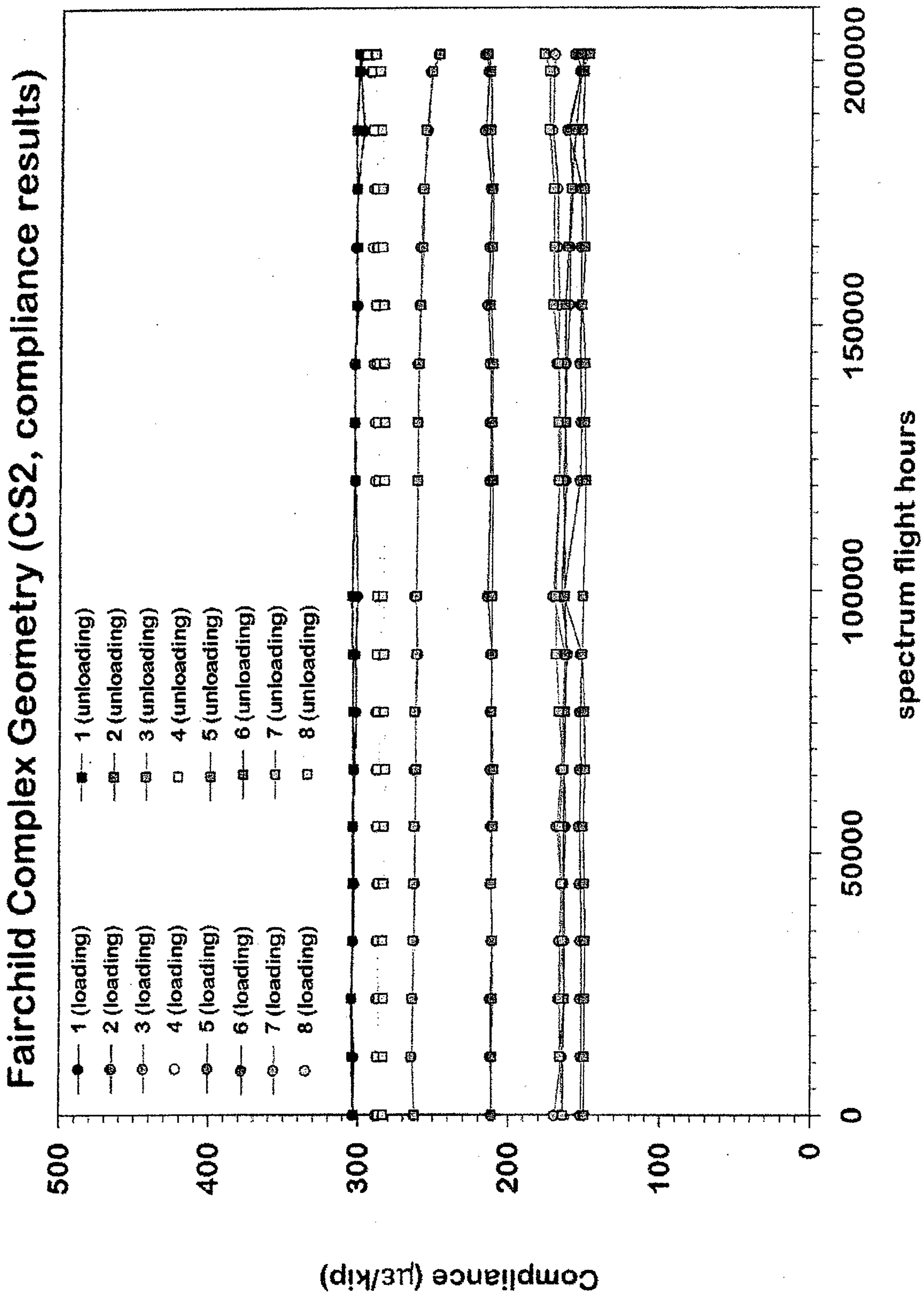
Specimen CS1 Strain Gage Output (SFH 60520)
1
2
3
4
5
6
7
8
compliance determined
through this portion
of load-strain trace
load (lbs)
µstrain
0
500
1000
1500
2000
2500
3000
3500
4000
0
200
400
600
800
1000
1200
1400

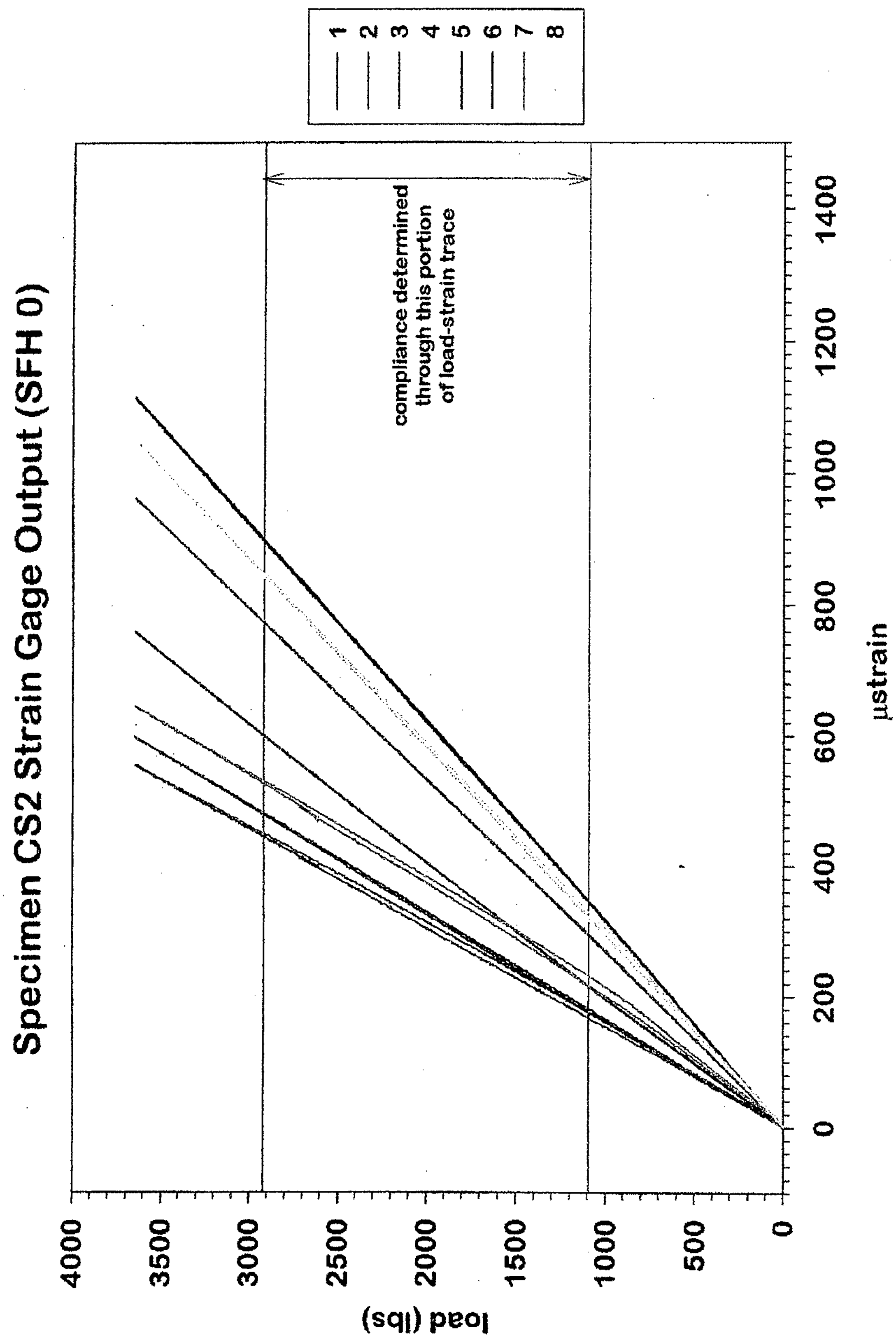

Specimen CS1 Strain Gage Output (SFH 82521)
load (lbs)
µstrain
compliance determined
through this portion
of load-strain trace
1
2
3
4
5
6
7
8
0
500
1000
1500
2000
2500
3000
3500
4000
200
400
600
800
1000
1200
1400

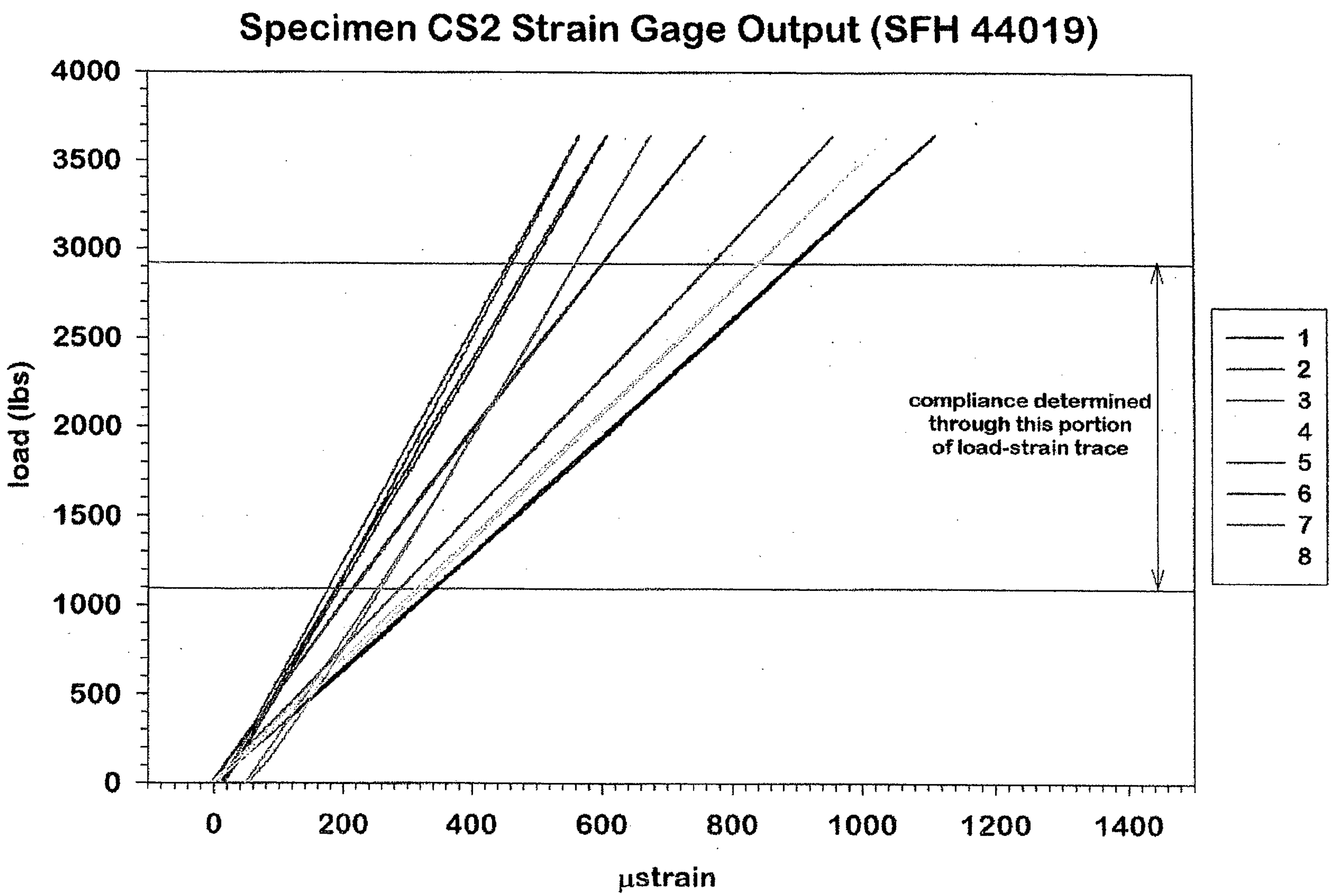
Specimen CS1 Strain Gage Output (SFH 99022)



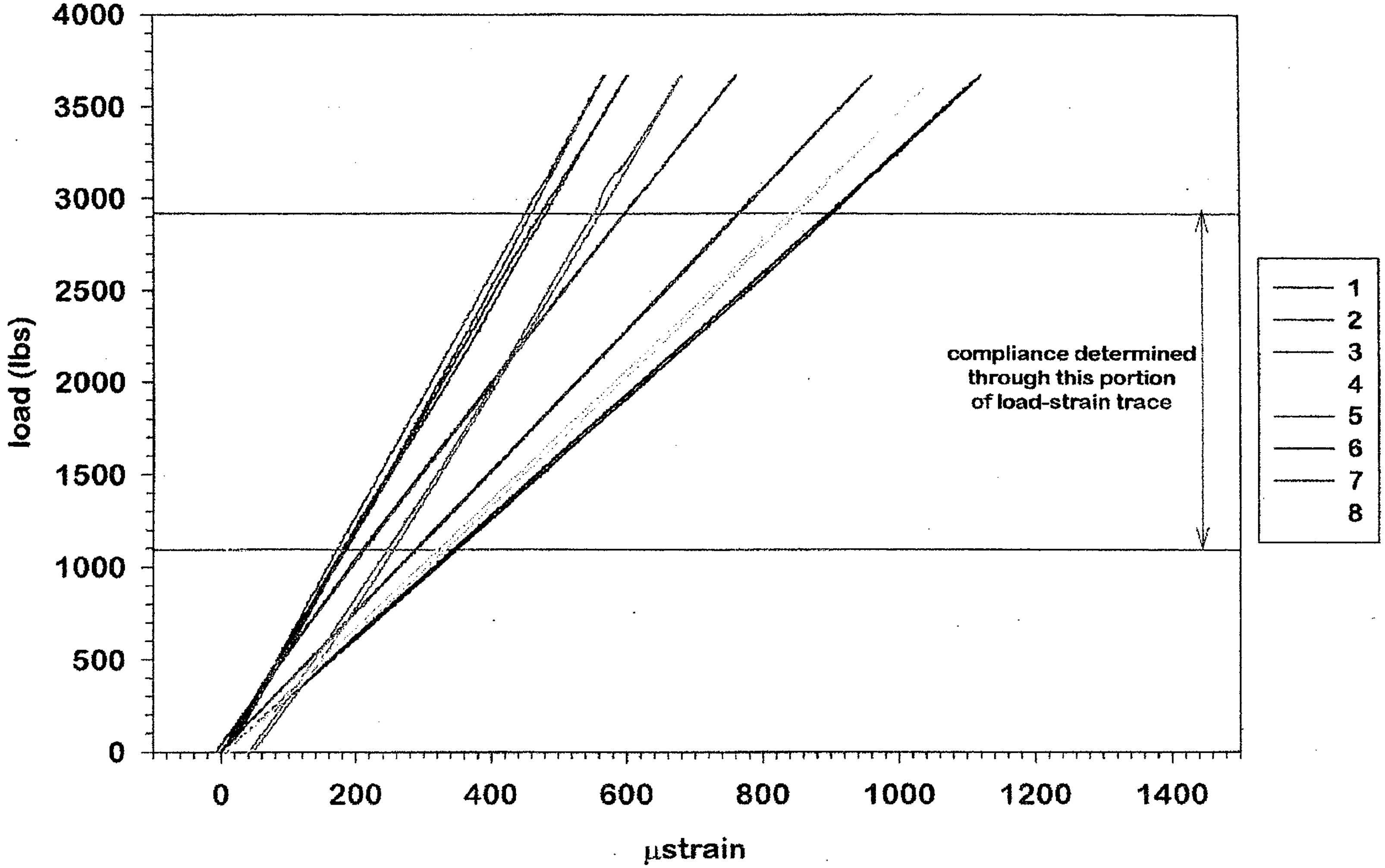

Specimen CS1 Strain Gage Output (SFH 121018)
compliance determined
through this portion
of load-strain trace
load (lbs)
µstrain
0
500
1000
1500
2000
2500
3000
3500
4000
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8

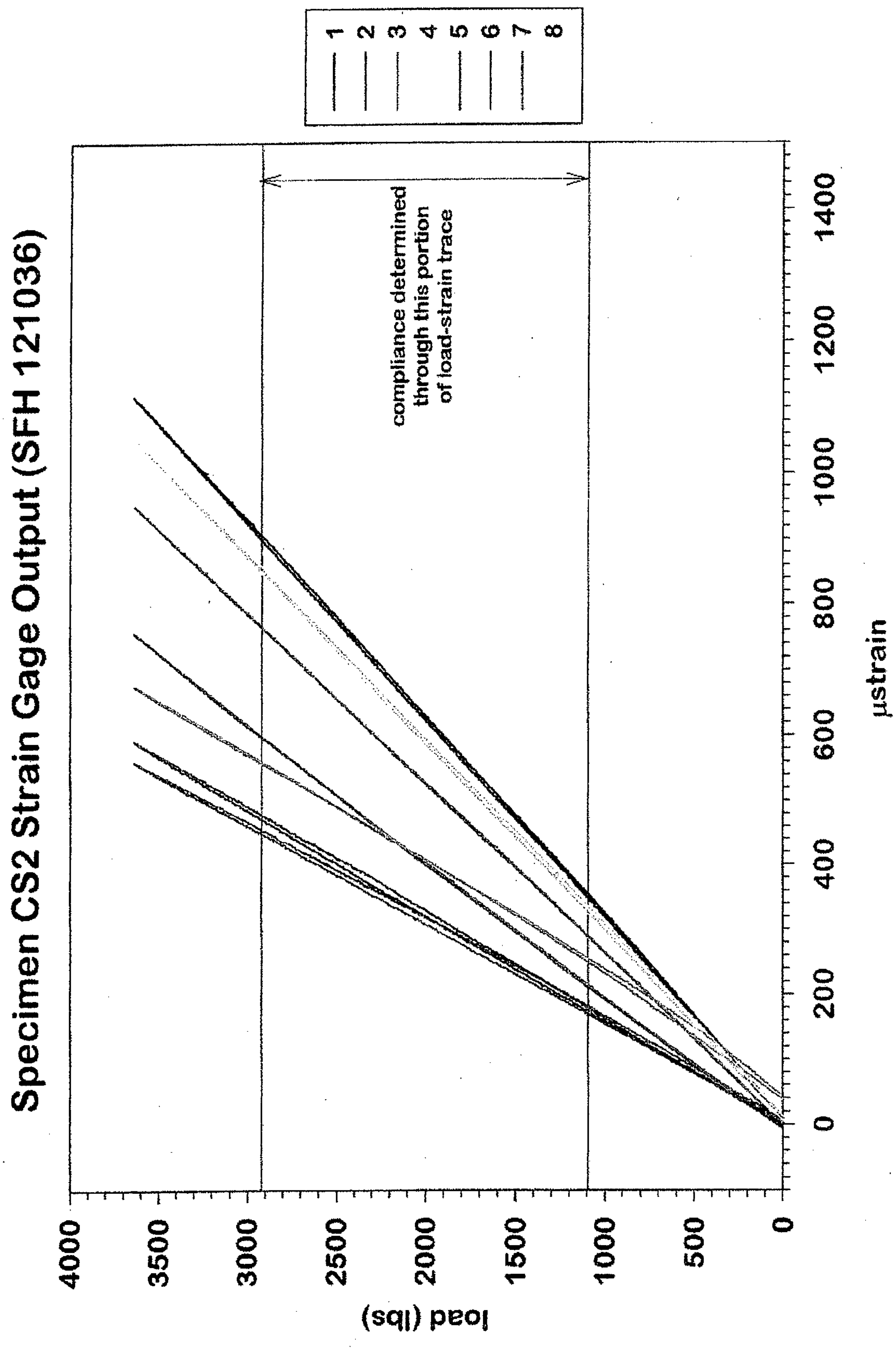

Fairchild Complex Geometry (CS2, compliance results)
1 (loading)
2 (loading)
3 (loading)
4 (loading)
5 (loading)
6 (loading)
7 (loading)
8 (loading)
1 (unloading)
2 (unloading)
3 (unloading)
4 (unloading)
5 (unloading)
6 (unloading)
7 (unloading)
8 (unloading)
Compliance (με/kip)
500
400
300
200
100
0
0
50000
100000
150000
200000
spectrum flight hours


Specimen CS2 Strain Gage Output (SFH 0)
compliance determined
through this portion
of load-strain trace
load (lbs)
μstrain
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8

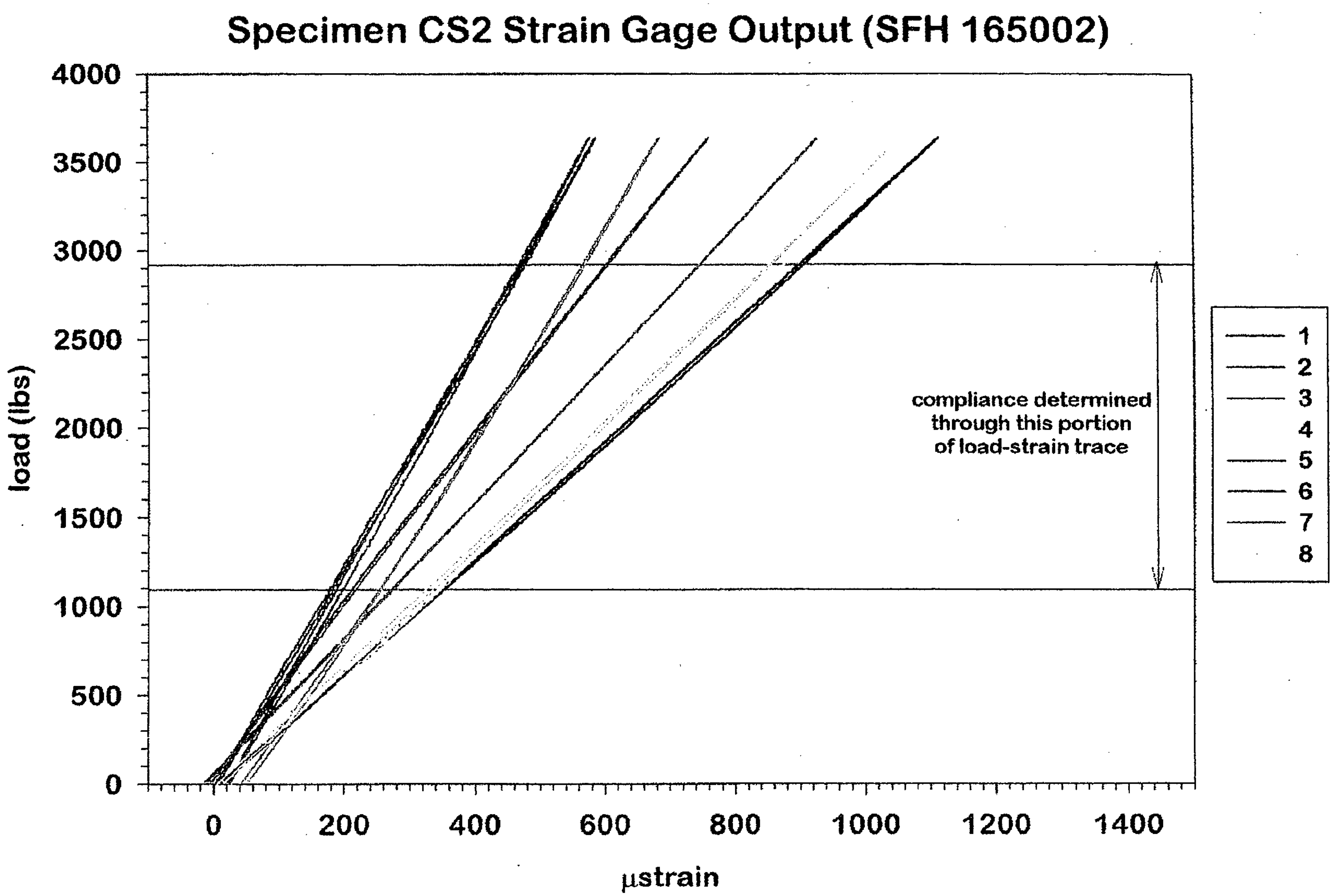

Specimen CS2 Strain Gage Output (SFH 44019)
load (lbs)
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
µstrain
compliance determined through this portion of load-strain trace
1
2
3
4
5
6
7
8

Specimen CS2 Strain Gage Output (SFH 88041)



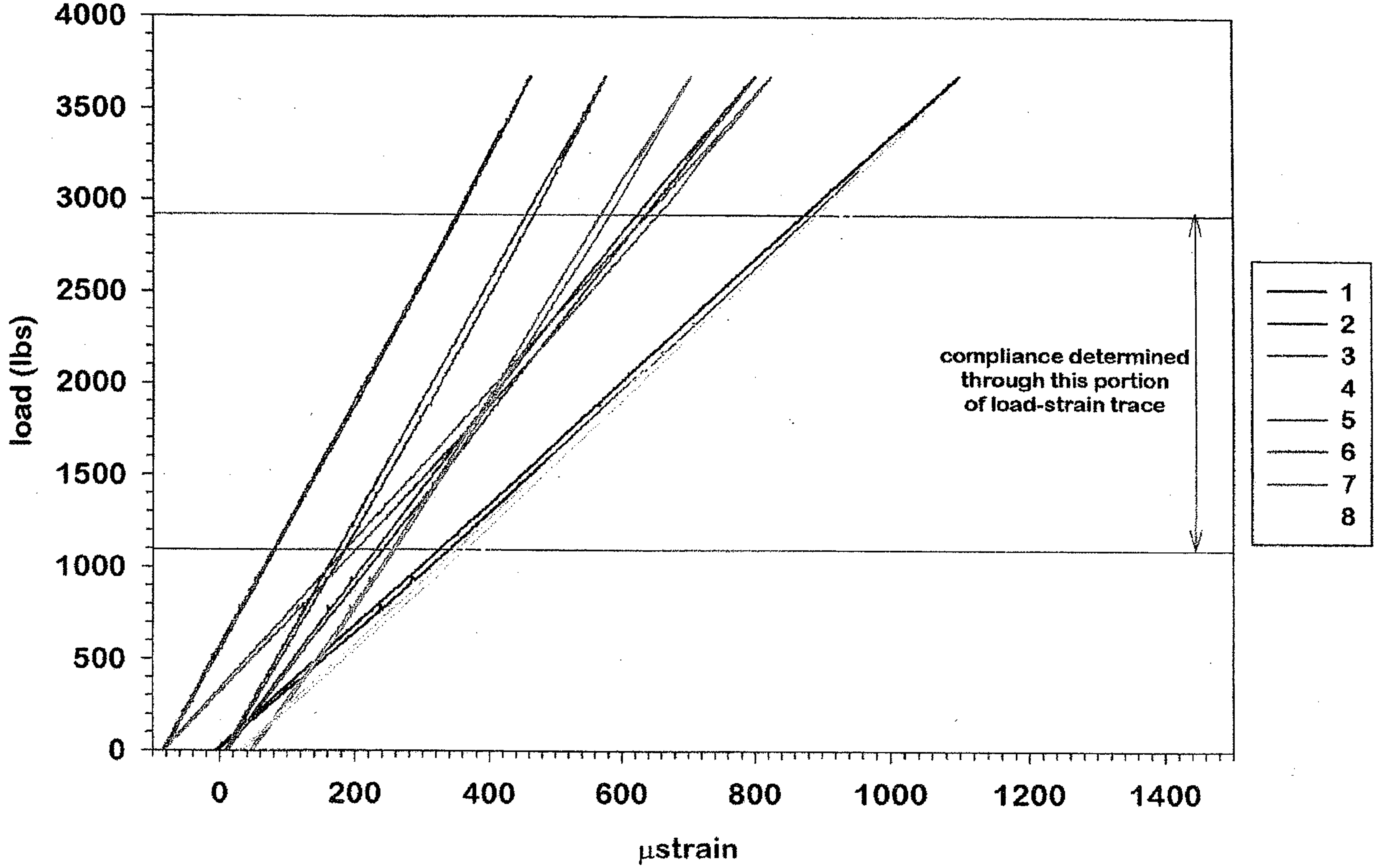


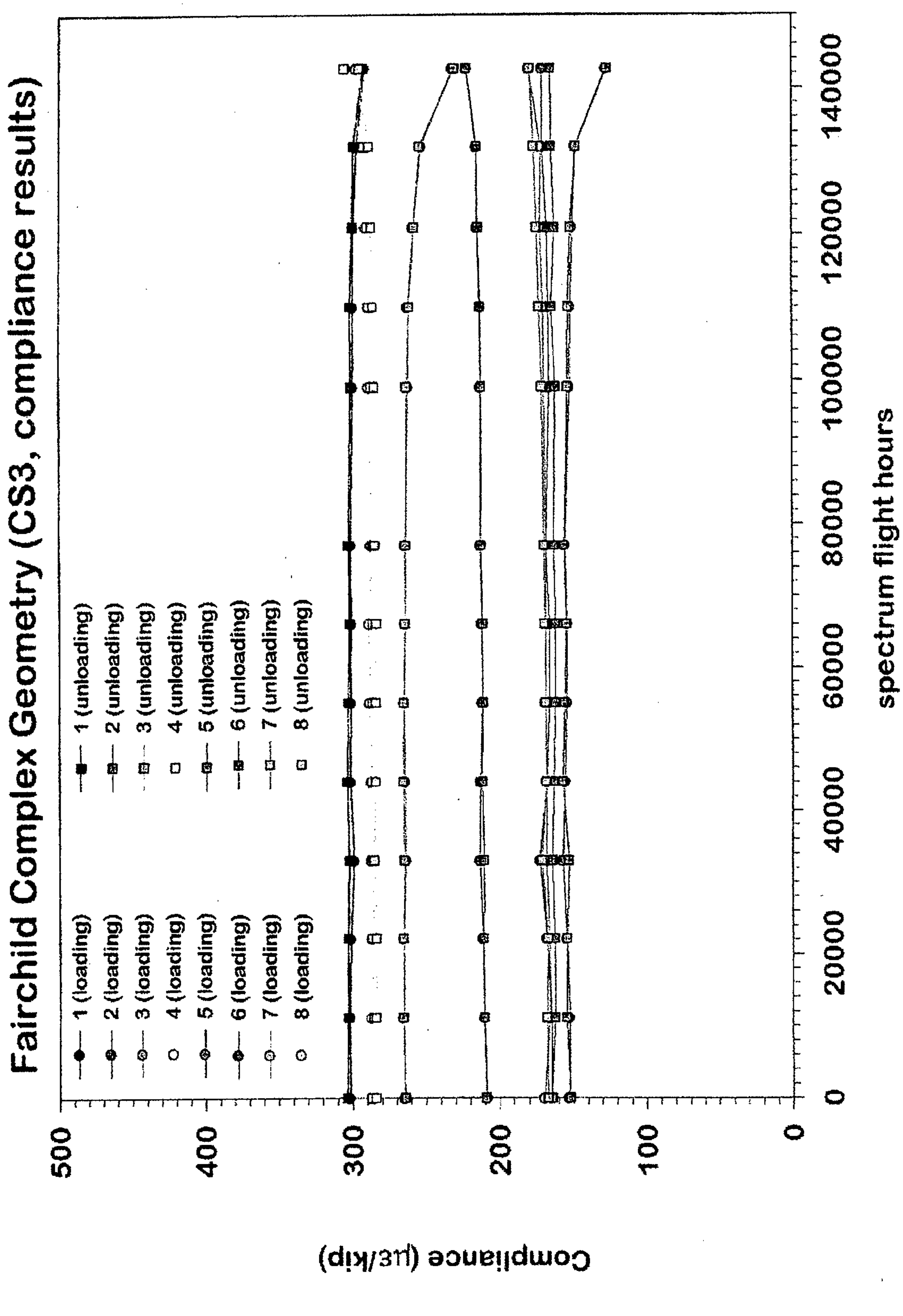
Specimen CS2 Strain Gage Output (SFH 121036)
compliance determined
through this portion
of load-strain trace
load (lbs)
µstrain
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8

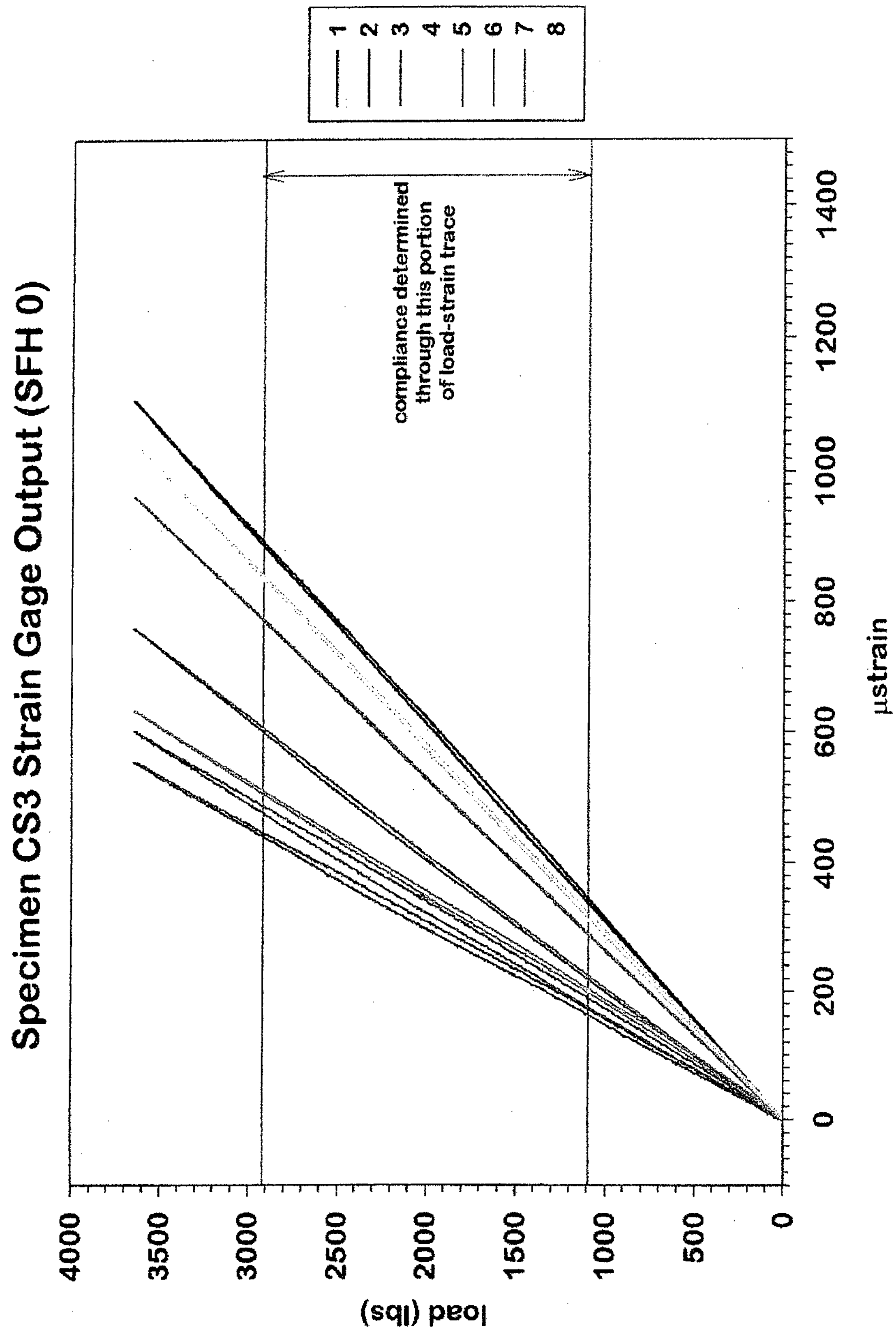


Specimen CS2 Strain Gage Output (SFH 165002)
load (lbs)
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400
μstrain
compliance determined through this portion of load-strain trace
1
2
3
4
5
6
7
8

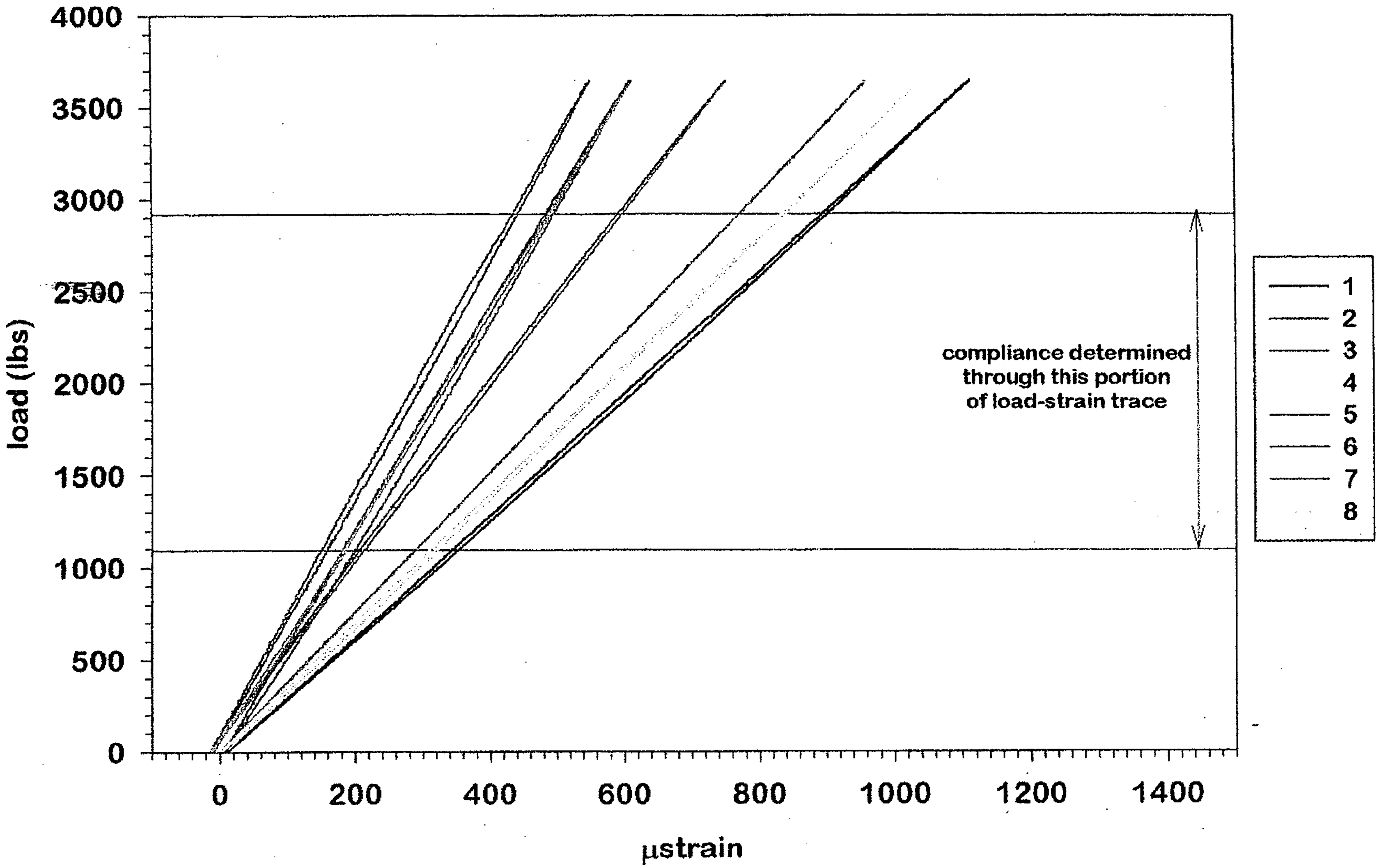
Specimen CS2 Strain Gage Output (SFH 201229)

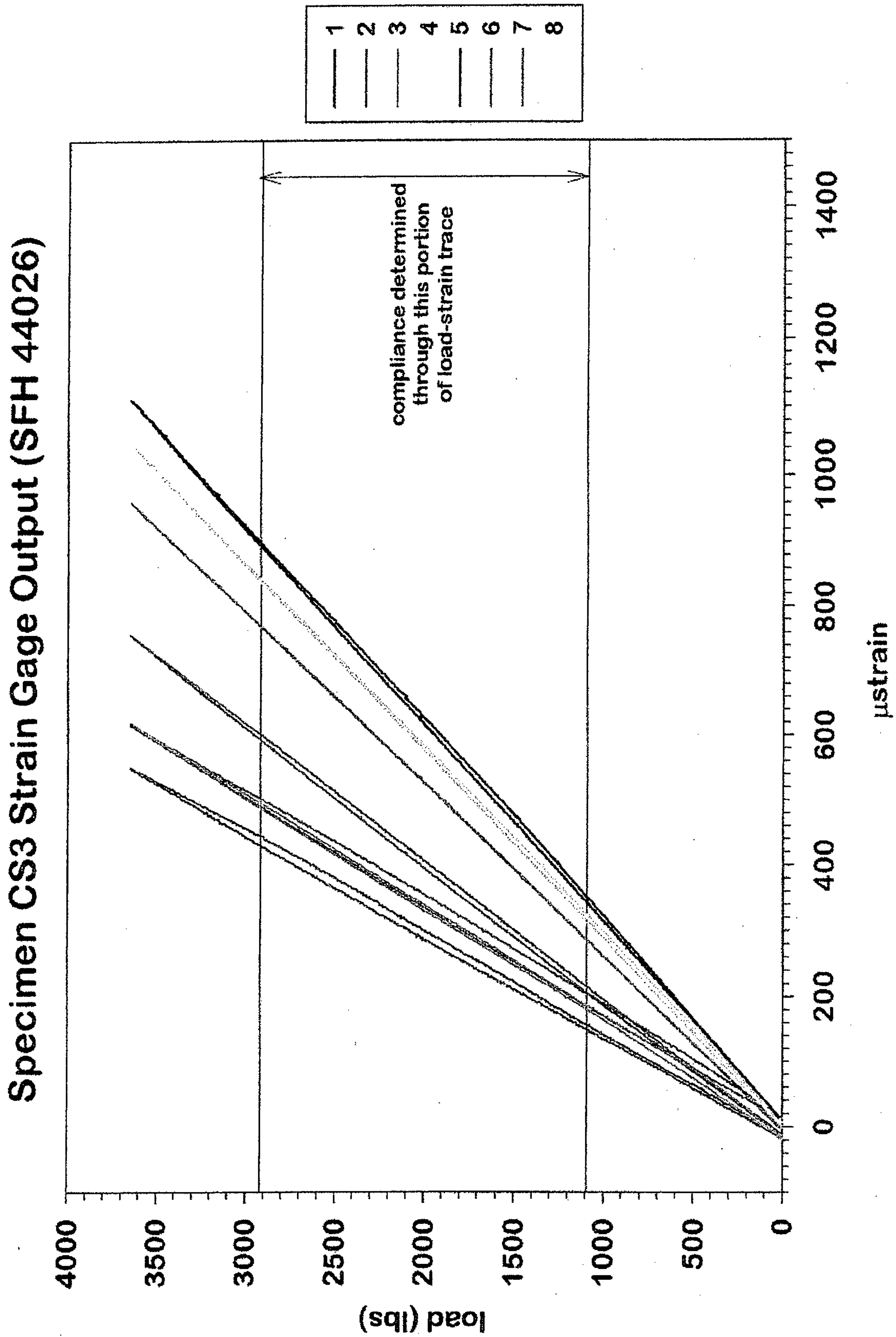



Fairchild Complex Geometry (CS3, compliance results)
Compliance (με/kip)
spectrum flight hours
1 (loading)
2 (loading)
3 (loading)
4 (loading)
5 (loading)
6 (loading)
7 (loading)
8 (loading)
1 (unloading)
2 (unloading)
3 (unloading)
4 (unloading)
5 (unloading)
6 (unloading)
7 (unloading)
8 (unloading)
0
100
200
300
400
500
0
20000
40000
60000
80000
100000
120000
140000

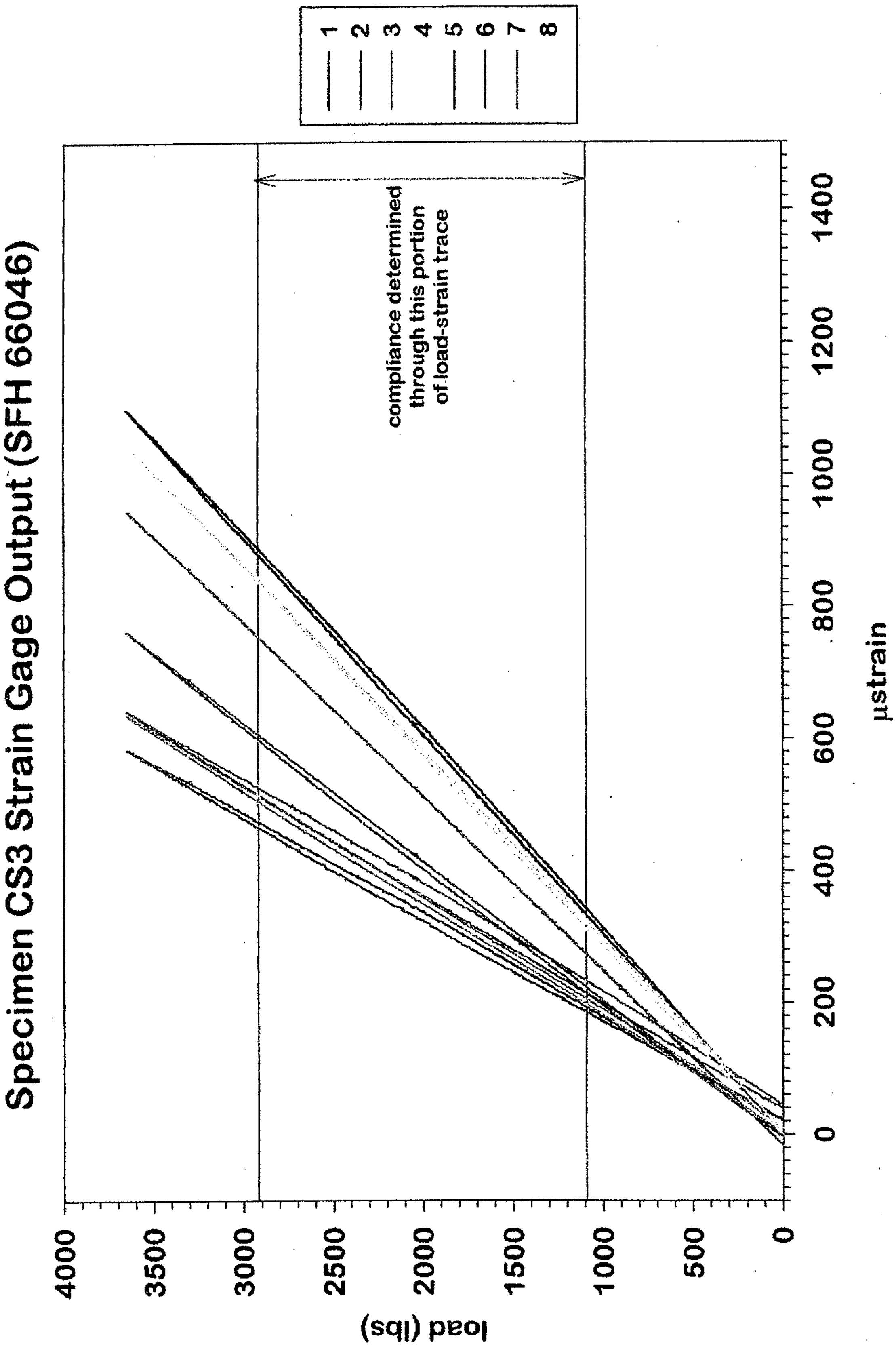

Specimen CS3 Strain Gage Output (SFH 0)
compliance determined through this portion of load-strain trace
load (lbs)
µstrain
0
500
1000
1500
2000
2500
3000
3500
4000
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8

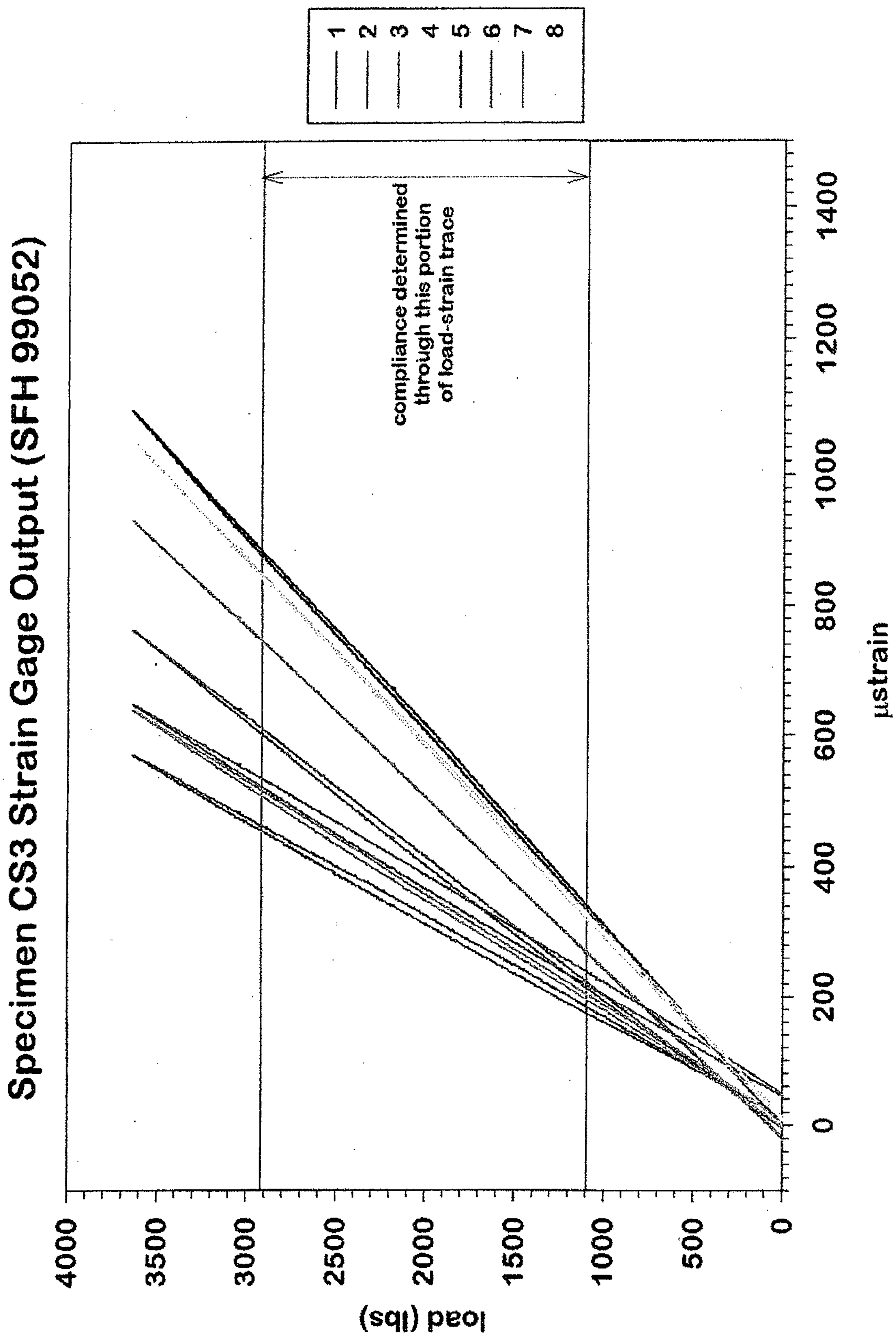
Specimen CS3 Strain Gage Output (SFH 22126)



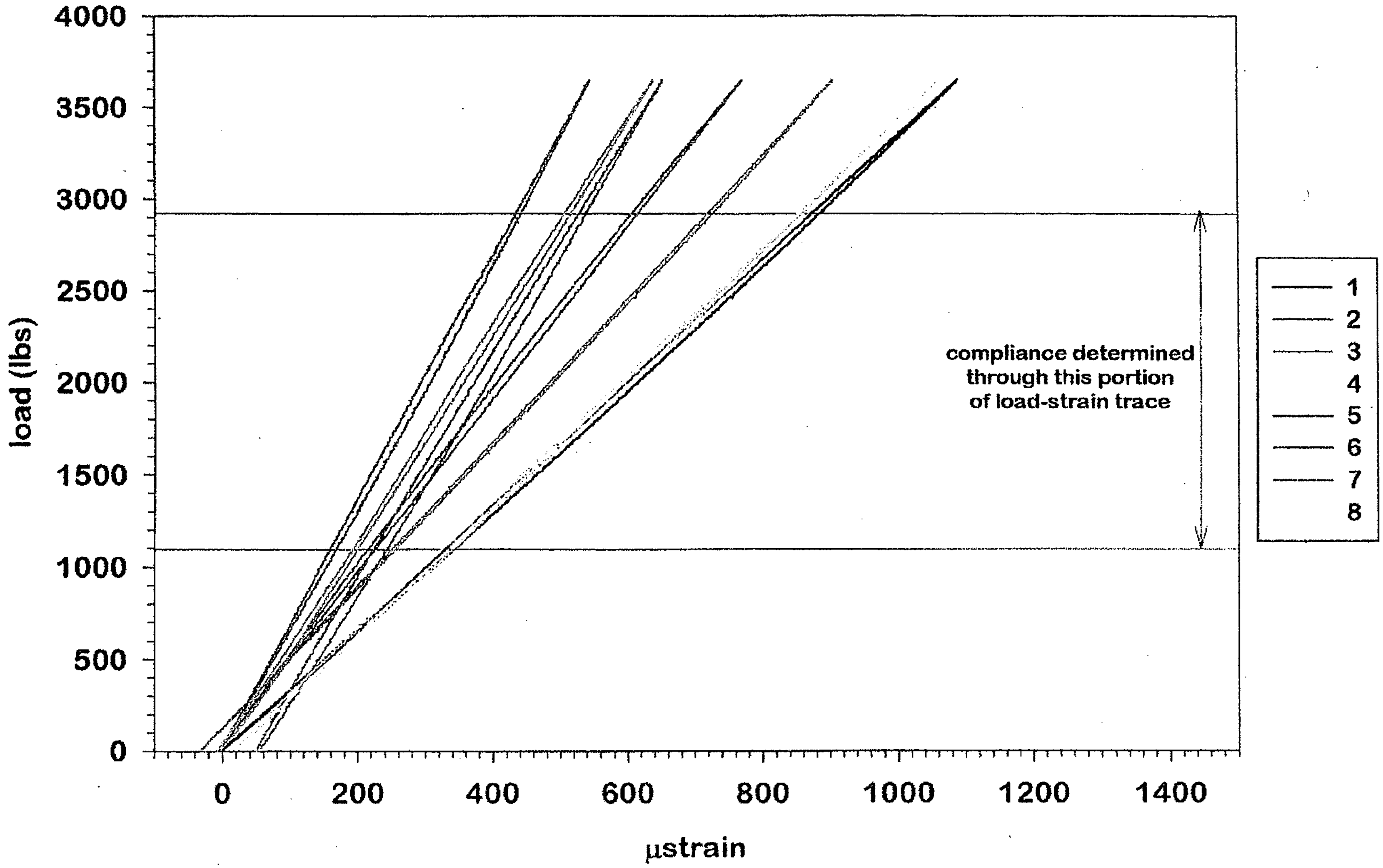


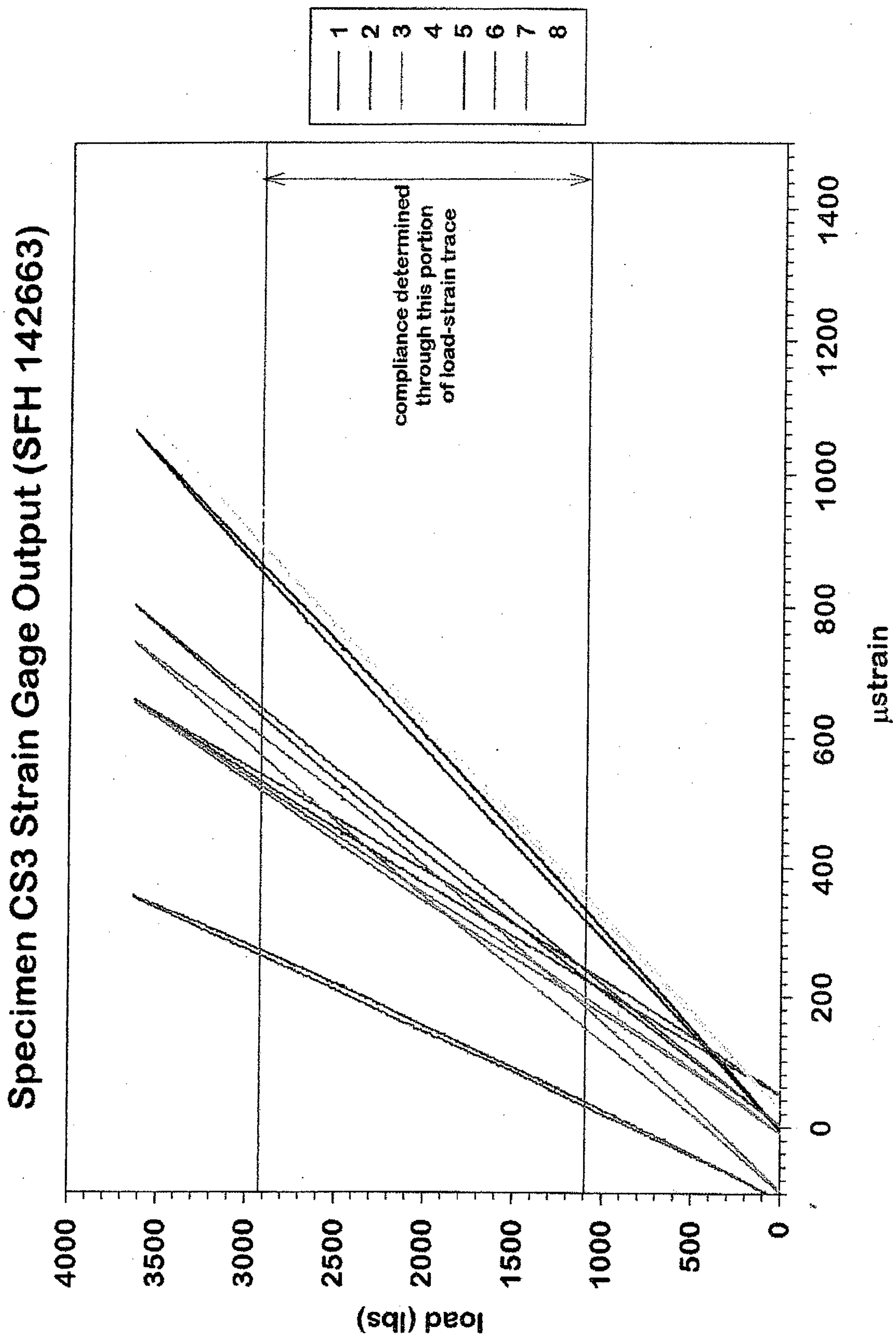
Specimen CS3 Strain Gage Output (SFH 44026)
compliance determined
through this portion
of load-strain trace
load (lbs)
µstrain
0
500
1000
1500
2000
2500
3000
3500
4000
0
200
400
600
800
1000
1200
1400
1
2
3
4
5
6
7
8


Specimen CS3 Strain Gage Output (SFH 66046)
load (lbs)
µstrain
compliance determined
through this portion
of load-strain trace
1
2
3
4
5
6
7
8
0
500
1000
1500
2000
2500
3000
3500
4000
200
400
600
800
1000
1200
1400


Specimen CS3 Strain Gage Output (SFH 99052)
load (lbs)
µstrain
compliance determined through this portion of load-strain trace
1
2
3
4
5
6
7
8
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
1200
1400

Specimen CS3 Strain Gage Output (SFH 121020)





Specimen CS3 Strain Gage Output (SFH 142663)
load (lbs)
0
500
1000
1500
2000
2500
3000
3500
4000
μstrain
0
200
400
600
800
1000
1200
1400
compliance determined
through this portion
of load-strain trace
1
2
3
4
5
6
7
8

Analyzed Compliance Data

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-1
Current Flight Hours = 0.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	313.9	17.5	1.419
2	202.8	-19.5	1.554
3	265.4	6.1	1.175
4	295.1	6.6	1.338
5	167.6	-6.6	0.990
6	161.1	-2.4	1.136
7	175.8	26.3	2.562
8	287.8	11.0	1.620

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	314.4	12.5	1.259
2	203.1	-21.1	1.392
3	264.5	9.5	1.062
4	294.5	8.0	1.193
5	169.3	-5.8	0.971
6	159.1	10.3	0.948
7	168.2	46.9	1.416
8	285.0	14.7	1.080

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-2
Current Flight Hours = 5525.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	312.0	38.0	1.807
2	204.5	-42.9	1.389
3	265.3	10.5	1.241
4	294.6	13.1	1.231
5	168.5	-37.2	1.033
6	162.1	-28.2	1.464
7	171.1	38.8	2.244
8	287.9	20.1	1.627

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	313.0	23.1	1.214
2	201.6	-28.7	0.957
3	264.2	14.2	1.117
4	294.3	10.1	1.288
5	168.9	-25.1	0.985
6	157.9	-1.9	1.085
7	170.9	46.1	1.714
8	284.7	24.9	1.214

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-3
Current Flight Hours = 11014.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.5	43.8	1.710	1	313.4	23.7	1.288
2	203.8	-42.3	1.479	2	201.4	-29.3	1.032
3	264.4	13.2	1.244	3	264.4	14.0	1.204
4	294.4	13.5	1.265	4	293.4	12.0	1.369
5	167.9	-42.7	1.199	5	169.4	-30.3	1.032
6	162.0	-27.7	1.881	6	158.4	0.8	0.938
7	170.4	33.3	1.731	7	171.0	38.8	1.750
8	287.2	21.9	1.524	8	284.0	24.8	1.178

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-4
Current Flight Hours = 16515.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.4	38.4	1.641	1	313.5	21.5	1.259
2	203.7	-41.4	1.636	2	202.7	-31.6	1.114
3	265.0	9.3	1.158	3	264.6	11.6	1.187
4	293.6	18.0	1.200	4	294.8	10.8	1.281
5	168.3	-43.5	1.146	5	169.6	-33.0	0.960
6	162.3	-25.8	1.598	6	158.2	-0.9	0.992
7	173.2	38.9	2.449	7	170.0	50.1	1.415
8	288.5	25.6	1.668	8	284.5	31.7	1.215

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-5
Current Flight Hours = 22013.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.1	42.6	1.659	1	313.3	25.1	1.042
2	204.3	-44.8	1.439	2	202.7	-34.0	1.356
3	265.1	10.5	1.193	3	264.0	13.7	1.017
4	294.7	15.8	1.270	4	295.5	9.8	1.252
5	168.9	-50.1	1.242	5	169.3	-37.2	0.915
6	162.7	-29.9	1.605	6	158.0	-4.9	0.944
7	172.2	33.7	2.238	7	170.3	41.0	1.286
8	287.4	27.9	1.590	8	284.1	31.5	1.041

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-6
Current Flight Hours = 27512.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.8	37.6	1.464	1	313.2	20.9	1.116
2	204.9	-40.6	1.549	2	203.0	-28.7	1.028
3	264.1	7.6	1.075	3	264.4	9.0	1.057
4	293.9	18.2	1.240	4	295.5	12.0	1.131
5	168.5	-36.8	1.016	5	169.4	-24.4	0.870
6	163.9	-29.0	1.842	6	158.6	-0.9	0.897
7	171.5	40.4	1.895	7	170.4	47.3	1.547
8	288.4	25.7	1.362	8	285.3	29.1	0.998

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-7
Current Flight Hours = 33019.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.3	39.5	1.551	1	313.2	23.9	1.155
2	204.5	-43.6	1.683	2	203.0	-32.8	1.028
3	264.2	8.7	1.126	3	263.7	11.5	1.123
4	294.1	18.0	1.289	4	294.7	13.4	1.178
5	168.7	-51.4	1.136	5	169.6	-39.8	0.912
6	163.0	-27.6	1.862	6	157.8	-1.6	0.968
7	173.5	35.1	2.488	7	169.2	48.1	1.522
8	288.6	30.2	1.625	8	284.3	36.4	1.104

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-8
Current Flight Hours = 38515.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.2	36.5	1.338	1	313.6	20.4	1.098
2	204.4	-39.0	1.387	2	203.1	-30.3	1.160
3	264.5	5.3	1.090	3	263.5	8.4	1.064
4	295.3	17.5	1.170	4	295.3	14.9	1.274
5	168.3	-39.8	1.018	5	169.6	-28.8	0.944
6	162.5	-24.0	1.654	6	158.1	1.2	0.959
7	173.4	39.6	2.211	7	170.1	52.2	1.311
8	288.7	29.0	1.492	8	285.0	33.6	1.035

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-9
Current Flight Hours = 45725.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.9	42.1	1.642
2	204.6	-46.3	1.682
3	264.2	7.5	1.218
4	295.3	16.5	1.309
5	168.9	-56.8	1.193
6	163.4	-31.7	1.722
7	173.1	32.1	2.624
8	288.4	31.0	1.801

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	312.4	27.7	1.357
2	203.8	-37.6	1.095
3	263.3	10.8	1.113
4	295.4	14.1	1.215
5	169.6	-43.1	0.924
6	157.9	-2.7	0.951
7	169.5	43.8	1.367
8	284.6	35.2	1.118

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-10
Current Flight Hours = 49517.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.0	34.7	1.623
2	204.5	-37.3	1.302
3	263.9	0.9	1.207
4	293.7	23.5	1.182
5	167.8	-38.7	0.985
6	162.6	-20.9	1.727
7	173.6	34.5	1.978
8	288.4	31.8	1.489

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	312.8	17.9	1.109
2	202.9	-27.1	1.146
3	262.6	4.3	1.076
4	296.0	16.9	1.146
5	168.1	-24.5	0.891
6	159.3	6.4	0.880
7	171.4	49.4	1.335
8	285.0	36.9	1.084

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-11
Current Flight Hours = 55014.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.6	39.7	1.761	1	312.1	24.5	1.327
2	205.7	-44.6	1.337	2	203.2	-34.0	1.370
3	263.5	5.6	1.302	3	262.2	8.2	1.182
4	295.4	18.8	1.238	4	295.1	16.1	1.373
5	168.1	-55.0	1.396	5	168.8	-42.4	1.046
6	163.9	-31.0	1.926	6	157.3	-2.8	1.221
7	174.0	33.2	2.457	7	169.5	46.5	1.386
8	288.5	35.0	1.854	8	284.4	40.1	1.240

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-12
Current Flight Hours = 60520.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.6	35.2	1.504	1	312.2	20.7	1.143
2	204.7	-39.3	1.349	2	203.6	-31.8	1.123
3	263.2	0.9	1.138	3	262.4	2.6	1.088
4	296.5	16.5	1.251	4	295.5	16.4	1.169
5	167.7	-46.5	1.461	5	168.8	-35.5	0.932
6	162.5	-25.5	1.244	6	157.6	0.6	0.880
7	173.0	38.2	2.696	7	169.5	49.4	1.274
8	288.3	34.8	1.634	8	284.5	38.9	1.103

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-13
Current Flight Hours = 66022.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.5	36.1	1.529	1	312.5	18.6	1.121
2	204.6	-40.4	1.374	2	202.8	-27.8	1.189
3	262.4	0.8	1.187	3	261.9	1.6	1.168
4	294.6	22.2	1.203	4	295.8	17.8	1.360
5	167.5	-49.7	1.110	5	167.9	-30.7	0.962
6	162.9	-25.0	1.857	6	157.5	9.2	0.971
7	172.5	37.2	2.186	7	171.8	44.6	1.492
8	288.8	32.4	1.511	8	284.7	36.0	1.205

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-14
Current Flight Hours = 71527.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.3	32.6	1.433	1	311.9	18.8	1.201
2	204.5	-35.3	1.510	2	203.5	-27.2	1.112
3	262.7	-3.4	1.158	3	261.7	-1.6	1.153
4	295.8	23.1	1.246	4	295.9	20.3	1.174
5	166.7	-45.5	1.016	5	167.8	-34.3	0.937
6	163.2	-25.3	1.560	6	158.9	-0.1	0.940
7	173.1	38.8	2.260	7	170.8	50.1	1.413
8	288.9	36.9	1.513	8	285.5	41.3	1.117

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-15
Current Flight Hours = 77024.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.8	35.2	1.696	1	313.0	15.2	1.258
2	205.3	-38.4	1.460	2	203.5	-24.9	1.267
3	262.3	-4.0	1.202	3	261.7	-5.2	1.170
4	296.2	25.2	1.265	4	296.6	22.3	1.249
5	166.5	-50.9	1.049	5	167.3	-33.2	0.994
6	164.1	-26.2	1.813	6	158.8	6.9	0.986
7	174.8	33.0	2.416	7	172.5	45.3	1.496
8	289.4	37.1	1.791	8	285.4	40.4	1.252

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-16
Current Flight Hours = 82521.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.9	31.3	1.419	1	312.3	15.8	1.245
2	204.6	-32.5	1.471	2	204.4	-27.1	1.109
3	261.9	-8.8	1.160	3	261.1	-7.7	1.127
4	297.1	26.4	1.183	4	296.5	25.1	1.151
5	165.6	-47.0	0.982	5	166.8	-37.3	0.918
6	162.6	-23.1	1.282	6	158.6	0.6	0.926
7	174.6	40.7	2.266	7	170.3	54.6	1.333
8	289.7	39.7	1.405	8	285.1	46.1	1.181

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-17
Current Flight Hours = 88004.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	304.9	55.5	1.286
2	209.7	-52.3	1.305
3	259.7	4.5	1.189
4	296.2	35.1	1.272
5	169.6	-75.5	1.342
6	172.3	-31.7	1.302
7	176.6	27.2	1.756
8	288.0	22.7	1.435

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	311.6	22.8	1.424
2	204.3	-28.8	1.129
3	260.3	-1.9	1.247
4	296.5	33.7	1.382
5	164.8	-42.0	1.055
6	162.4	18.2	1.118
7	174.9	43.9	1.578
8	286.5	20.8	1.375

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-18
Current Flight Hours = 93514.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	309.7	34.0	1.428
2	206.0	-39.4	1.125
3	260.8	-10.6	1.149
4	296.7	28.0	1.272
5	165.0	-49.7	0.965
6	164.7	-9.0	1.283
7	174.5	43.6	2.308
8	290.5	14.9	1.466

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	312.3	15.6	1.109
2	204.7	-30.1	1.108
3	260.3	-11.0	1.242
4	296.1	29.5	1.157
5	165.4	-36.9	0.900
6	159.3	20.2	0.889
7	171.9	56.6	1.501
8	285.5	23.3	1.324

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = csl-19
Current Flight Hours = 99022.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	309.4	35.1	1.691	1	311.7	15.7	1.231
2	206.4	-42.0	1.723	2	204.7	-29.2	1.179
3	259.8	-11.7	1.348	3	259.1	-14.1	1.216
4	297.3	33.9	1.328	4	297.6	33.4	1.367
5	164.4	-60.9	1.609	5	163.9	-46.7	0.986
6	164.4	-9.8	1.839	6	161.0	17.2	1.120
7	174.8	42.1	2.128	7	174.0	51.1	1.696
8	290.1	21.8	1.588	8	287.3	25.2	1.280

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = csl-20
Current Flight Hours = 104501.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.6	25.4	1.658	1	311.8	12.1	1.220
2	205.2	-26.7	1.289	2	204.5	-20.6	1.195
3	259.4	-29.2	1.204	3	258.3	-27.6	1.114
4	298.9	42.2	1.105	4	298.2	41.6	1.219
5	162.9	-30.7	0.937	5	163.1	-25.7	0.944
6	164.7	8.0	0.888	6	160.5	29.9	1.003
7	179.4	45.4	2.587	7	175.0	64.0	1.825
8	293.7	6.7	1.477	8	288.5	19.2	1.188

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-21
Current Flight Hours = 110003.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	309.4	30.7	1.455	1	311.7	12.8	1.310
2	205.8	-31.8	1.495	2	204.7	-22.6	1.122
3	257.8	-33.7	1.210	3	257.2	-35.2	1.210
4	299.2	45.2	1.266	4	299.3	44.6	1.182
5	160.7	-52.5	1.068	5	160.8	-48.5	0.922
6	163.5	4.9	1.332	6	161.2	24.0	0.969
7	176.0	45.1	2.445	7	175.5	53.5	1.880
8	292.6	13.7	1.481	8	288.6	23.4	1.227

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-22
Current Flight Hours = 115501.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	310.0	21.7	1.404	1	311.6	5.2	1.121
2	206.4	-23.1	1.392	2	205.8	-15.2	1.162
3	256.6	-52.4	1.209	3	255.2	-55.0	1.149
4	300.6	53.1	1.237	4	300.6	54.9	1.220
5	157.3	-54.0	0.905	5	157.2	-51.8	0.907
6	164.9	7.4	0.994	6	161.0	28.2	1.019
7	179.6	47.3	1.979	7	176.2	63.8	1.785
8	294.5	16.2	1.391	8	289.8	28.4	1.251

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs1-23
Current Flight Hours = 121018.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	-7.1	4.0	9.787	1	0.7	-6.9	5.027
2	215.3	-28.6	2.269	2	210.1	4.5	1.032
3	223.7	-98.7	5.874	3	228.5	-175.6	1.480
4	0.0	-2500.0	0.003	4	0.0	-2500.0	0.003
5	116.2	-152.1	3.275	5	112.6	-168.9	0.935
6	169.7	-21.7	2.068	6	165.0	11.6	1.350
7	181.3	54.7	1.873	7	181.3	67.7	1.497
8	304.2	37.0	1.549	8	299.4	50.8	1.542

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-2
Current Flight Hours = 0.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.4	15.2	1.267	1	303.0	14.2	1.284
2	211.1	-18.0	0.996	2	211.1	-18.0	1.063
3	262.8	4.7	1.064	3	262.6	6.5	1.039
4	288.4	0.4	1.121	4	286.8	6.8	1.166
5	163.9	-3.4	1.050	5	164.2	-0.8	1.044
6	152.1	-1.0	0.929	6	150.0	11.5	1.048
7	169.5	31.1	1.285	7	164.1	52.5	1.265
8	286.8	5.1	1.048	8	283.8	19.1	1.200

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-3
Current Flight Hours = 11014.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.8	28.4	1.488	1	304.3	17.7	1.064
2	211.8	-33.5	1.423	2	211.2	-27.6	1.257
3	264.1	13.9	1.071	3	264.8	12.6	1.131
4	287.6	4.1	1.200	4	287.2	6.8	1.120
5	164.5	-43.9	1.197	5	166.2	-33.6	1.163
6	152.0	-16.5	1.009	6	150.3	4.2	0.978
7	165.2	33.1	1.361	7	166.3	34.1	0.929
8	286.6	2.0	1.133	8	283.3	14.6	1.119

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-4
Current Flight Hours = 22017.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	304.4	9.0	1.332
2	211.9	-19.6	1.411
3	263.7	-1.4	1.137
4	287.9	0.8	1.149
5	163.0	7.7	0.988
6	152.3	13.9	0.906
7	166.9	78.6	1.804
8	287.6	-7.0	1.239

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	304.6	1.5	1.335
2	210.7	-13.4	1.149
3	264.2	-1.2	1.145
4	286.6	5.6	1.124
5	163.2	21.2	1.156
6	150.0	37.8	0.993
7	166.5	83.2	0.884
8	283.3	9.4	1.325

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-5
Current Flight Hours = 33050.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.4	11.5	1.292
2	210.9	-21.3	1.254
3	262.9	-0.7	1.146
4	287.9	-1.2	1.117
5	163.1	5.8	1.098
6	152.3	9.9	0.870
7	166.4	73.8	2.195
8	287.5	-4.8	1.228

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.9	4.6	1.219
2	210.9	-17.2	1.277
3	263.7	-1.2	1.096
4	287.4	2.3	1.115
5	164.4	11.8	1.053
6	149.9	25.6	0.919
7	164.4	80.5	0.910
8	284.1	9.3	1.237

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-6
Current Flight Hours = 44019.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.8	16.8	1.597	1	303.8	7.1	1.125
2	211.7	-23.2	1.459	2	211.6	-18.9	1.256
3	262.5	0.2	1.090	3	263.4	-0.4	1.100
4	287.6	2.9	1.156	4	286.8	5.9	1.192
5	163.9	1.2	1.087	5	164.5	12.9	1.291
6	152.9	1.3	1.034	6	150.1	23.5	0.959
7	165.5	72.7	1.791	7	165.4	76.8	0.924
8	286.8	-0.3	1.146	8	283.5	12.6	1.222

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-7
Current Flight Hours = 55047.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.5	12.4	1.188	1	304.1	3.3	1.141
2	211.6	-20.1	1.380	2	210.9	-14.2	1.271
3	262.4	-3.1	1.047	3	263.0	-1.7	1.078
4	287.6	3.9	1.044	4	287.8	5.6	1.096
5	162.5	10.6	1.118	5	164.0	20.3	0.954
6	153.7	10.0	1.028	6	151.1	35.9	0.910
7	168.5	70.6	1.385	7	166.9	84.7	0.897
8	288.1	-5.1	1.098	8	283.4	13.6	1.188

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-8
Current Flight Hours = 66024.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.9	19.3	1.258
2	212.0	-23.8	1.384
3	262.8	-0.4	1.083
4	288.3	6.2	1.093
5	164.0	1.4	1.150
6	153.0	1.5	1.061
7	165.5	74.7	2.313
8	287.0	4.0	1.100

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.5	9.8	0.980
2	210.5	-16.0	1.036
3	262.1	2.4	1.022
4	288.0	8.8	1.002
5	163.9	12.3	1.102
6	149.9	24.3	0.885
7	164.4	79.1	0.808
8	282.4	19.3	1.017

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-9
Current Flight Hours = 77074.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.8	28.4	1.586
2	212.0	-29.5	1.262
3	262.3	4.7	1.077
4	288.6	9.7	1.183
5	164.5	-21.5	1.318
6	153.1	-7.6	1.127
7	164.4	61.5	1.732
8	286.8	8.0	1.174

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.9	15.2	1.096
2	211.7	-23.2	1.189
3	263.0	4.3	1.075
4	288.0	12.6	1.085
5	163.1	-5.2	1.002
6	150.5	13.7	1.000
7	167.3	57.0	0.888
8	283.4	21.8	1.161

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-10
Current Flight Hours = 88041.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.3	23.8	1.366	1	304.1	10.2	1.048
2	211.8	-26.9	1.496	2	211.3	-19.4	1.441
3	260.8	2.3	1.108	3	261.9	1.8	1.233
4	287.1	13.6	1.128	4	288.2	14.4	1.136
5	161.4	-4.1	1.305	5	162.8	10.5	1.618
6	152.4	-1.5	1.220	6	152.0	26.1	1.024
7	163.6	72.5	1.474	7	169.3	69.6	1.014
8	285.9	8.5	1.112	8	283.5	19.8	1.446

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-11
Current Flight Hours = 99005.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.9	21.7	1.322	1	304.6	3.4	0.983
2	214.6	-24.4	1.104	2	211.5	-11.4	1.188
3	262.8	-7.6	1.181	3	262.1	-5.1	0.920
4	287.6	12.1	1.188	4	288.2	14.6	0.991
5	165.7	-1.4	1.278	5	163.6	19.0	0.936
6	164.4	-17.1	2.467	6	151.5	33.2	0.981
7	171.0	55.9	1.290	7	169.7	69.6	0.811
8	287.0	-3.5	1.084	8	284.3	11.3	1.175

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-13
Current Flight Hours = 121036.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.7	26.1	1.405	1	303.0	16.8	1.159
2	212.8	-28.4	1.541	2	211.2	-19.5	1.147
3	261.0	2.8	1.079	3	261.3	2.7	1.115
4	289.3	11.7	1.180	4	287.7	18.2	1.181
5	162.6	-10.9	1.180	5	164.4	-2.1	1.161
6	153.5	-7.4	1.207	6	149.6	17.5	1.032
7	167.2	68.2	1.522	7	167.7	70.0	0.886
8	287.4	10.2	1.087	8	283.5	25.3	1.218

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-14
Current Flight Hours = 132055.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.9	25.1	1.216	1	303.5	14.6	1.122
2	212.9	-28.1	1.161	2	211.8	-21.6	1.142
3	261.1	-0.7	1.018	3	261.5	-1.0	1.138
4	289.6	15.0	1.054	4	288.3	20.3	1.076
5	163.7	-14.2	0.986	5	163.2	-1.8	1.141
6	152.9	2.0	0.901	6	150.7	25.8	1.068
7	166.6	72.8	1.811	7	168.2	70.5	0.878
8	287.6	11.0	1.163	8	283.3	25.8	1.254

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-15
Current Flight Hours = 143035.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.5	19.6	1.463	1	303.0	10.3	1.170
2	212.9	-21.5	1.187	2	211.2	-13.0	1.179
3	261.2	-8.2	1.194	3	260.6	-6.7	1.224
4	290.3	14.4	1.212	4	287.6	22.9	1.205
5	162.8	-3.3	1.544	5	163.8	6.3	1.164
6	153.8	5.1	1.067	6	150.6	31.7	0.934
7	168.8	73.4	1.771	7	168.0	79.2	1.052
8	288.6	5.2	1.324	8	283.9	22.4	1.240

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-16
Current Flight Hours = 154033.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.4	31.5	1.607	1	302.5	16.2	1.160
2	214.9	-32.5	1.340	2	213.1	-19.7	1.083
3	260.1	-2.7	1.196	3	259.8	-6.4	1.094
4	289.5	21.6	1.257	4	289.6	27.3	1.077
5	160.6	-21.3	1.442	5	163.7	-8.2	1.352
6	153.6	-0.8	1.333	6	152.7	28.8	1.003
7	167.9	41.3	1.823	7	171.9	41.8	1.029
8	287.4	8.6	1.279	8	284.2	22.7	1.268

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-17
Current Flight Hours = 165002.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.0	24.6	1.349	1	302.2	16.9	1.126
2	213.8	-26.8	1.585	2	211.9	-17.1	1.203
3	259.7	-11.9	1.129	3	258.4	-9.7	1.064
4	291.7	22.1	1.191	4	289.1	31.4	1.204
5	160.8	-1.0	1.117	5	161.9	4.0	1.035
6	153.3	17.0	0.962	6	150.8	32.8	0.994
7	169.0	72.1	1.630	7	171.4	68.3	1.010
8	288.7	7.6	1.170	8	285.2	24.0	1.297

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-18
Current Flight Hours = 176050.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	302.4	17.5	1.500	1	302.5	6.2	1.221
2	213.1	-17.3	1.583	2	211.9	-7.7	1.108
3	258.6	-20.1	1.183	3	258.0	-21.5	1.162
4	291.0	26.8	1.134	4	289.6	35.2	1.219
5	159.2	-6.2	1.055	5	160.1	2.3	1.047
6	153.4	7.8	1.024	6	151.1	34.5	1.133
7	169.1	75.4	1.402	7	171.8	75.8	0.883
8	289.4	7.9	1.211	8	285.5	24.5	1.381

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-19
Current Flight Hours = 187008.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	298.1	34.9	1.499
2	217.1	-28.3	1.303
3	255.6	-17.1	1.281
4	291.6	35.9	1.360
5	162.0	-39.8	1.015
6	162.7	-16.2	2.214
7	172.6	59.1	1.745
8	289.9	15.9	1.105

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	303.4	9.3	1.293
2	213.4	-9.9	1.309
3	256.8	-26.7	1.160
4	291.9	42.7	1.337
5	157.7	-18.0	1.179
6	153.0	28.3	1.201
7	175.1	62.3	1.116
8	286.4	31.2	1.385

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs2-20
Current Flight Hours = 198018.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.0	16.1	1.592
2	215.1	-14.7	1.842
3	253.6	-45.1	1.466
4	294.1	44.7	1.311
5	154.4	-41.1	1.118
6	153.9	4.6	1.012
7	171.9	71.5	1.359
8	292.4	14.2	1.203

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.7	0.4	1.248
2	213.7	-0.2	1.088
3	252.8	-56.9	1.171
4	293.2	58.4	1.235
5	153.9	-33.0	1.044
6	151.9	31.6	1.141
7	174.9	72.1	0.903
8	287.9	33.3	1.462

STRAIN LOAD/UNLOAD ANALYZER

```
           File Prefix = cs2-21
  Current Flight Hours = 201229.0
       Number of Files =   3 with  6 junk lines each
Number of Strain Gages =   8
```

----------> FILE = averages of all   3 files

LOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.1	14.3	1.952
2	217.3	-15.3	1.686
3	248.7	-65.3	2.241
4	296.2	60.8	1.488
5	151.3	-90.5	1.040
6	157.8	-11.2	3.181
7	171.2	66.1	1.733
8	293.2	28.0	1.131

UNLOADING:

strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.6	-6.0	1.195
2	215.9	2.1	1.149
3	248.3	-88.2	1.159
4	297.0	75.1	1.240
5	148.5	-80.8	0.975
6	154.3	16.0	1.169
7	178.5	60.3	1.005
8	290.8	43.9	1.282

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-4
Current Flight Hours = 0.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.8	15.2	1.575	1	303.6	2.8	1.076
2	208.5	-12.9	1.335	2	209.0	-7.0	0.967
3	264.7	-3.4	1.114	3	264.2	0.2	1.078
4	286.3	-3.9	1.096	4	287.0	-3.7	1.098
5	153.1	-8.7	1.306	5	152.2	2.5	1.053
6	164.6	-7.1	1.186	6	164.6	7.9	1.155
7	169.8	8.9	1.253	7	167.5	19.9	0.898
8	287.2	-3.3	1.052	8	284.5	10.2	1.205

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-5
Current Flight Hours = 11093.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.8	16.9	1.464	1	302.8	4.6	1.477
2	210.2	-18.3	1.319	2	210.2	-9.7	1.084
3	265.4	-8.2	1.180	3	265.4	-7.9	1.226
4	286.5	-1.7	1.177	4	285.7	3.6	1.258
5	152.7	0.5	1.299	5	154.7	11.5	1.242
6	164.9	-2.4	1.112	6	162.4	27.6	1.054
7	166.2	9.6	1.048	7	168.0	12.8	0.855
8	287.0	-4.8	1.207	8	284.0	4.0	1.087

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-6
Current Flight Hours = 22126.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.9	26.4	1.553	1	302.6	12.4	0.994
2	210.9	-27.9	1.474	2	210.4	-17.7	0.786
3	265.3	-2.6	1.109	3	265.3	-3.2	0.983
4	286.8	0.7	1.153	4	286.5	5.4	1.103
5	154.3	-28.2	1.770	5	154.2	-9.8	1.202
6	167.9	-14.7	2.608	6	162.6	21.8	1.072
7	166.2	-1.8	1.510	7	167.3	2.9	0.853
8	286.6	2.2	1.314	8	283.8	10.0	1.068

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-7
Current Flight Hours = 33001.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	298.7	26.7	1.236	1	302.0	8.7	1.313
2	213.1	-27.7	1.278	2	210.0	-9.7	0.940
3	263.4	-3.0	1.151	3	264.6	-6.8	1.121
4	287.1	1.3	1.110	4	286.9	6.7	1.195
5	157.2	-20.5	1.749	5	152.8	11.9	1.136
6	172.4	-20.1	1.414	6	164.0	26.8	1.385
7	168.0	3.0	1.491	7	171.2	8.9	1.109
8	285.0	9.0	1.279	8	285.2	11.2	1.395

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-8
Current Flight Hours = 44026.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	301.0	24.9	1.584	1	303.1	9.4	0.921
2	212.4	-31.3	1.327	2	211.1	-17.3	0.854
3	264.2	-1.6	1.097	3	265.3	-5.6	0.993
4	287.0	1.2	1.106	4	286.7	6.5	1.082
5	155.3	-31.7	2.290	5	156.9	-15.9	1.084
6	167.6	-10.5	2.606	6	162.7	26.7	1.078
7	167.8	-5.9	1.266	7	168.2	1.2	0.887
8	287.1	4.5	1.466	8	284.0	13.2	0.996

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-9
Current Flight Hours = 55041.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.7	18.5	1.407	1	302.5	3.3	1.159
2	211.1	-21.1	1.328	2	210.7	-10.4	0.913
3	264.6	-12.3	1.224	3	264.9	-13.9	1.137
4	286.7	0.5	1.194	4	286.0	7.1	1.182
5	154.1	-3.7	1.251	5	155.5	10.7	1.205
6	165.8	6.8	1.266	6	161.9	41.8	1.117
7	168.6	7.4	1.132	7	168.4	16.7	0.927
8	288.1	1.7	1.334	8	283.9	13.5	1.243

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-10
Current Flight Hours = 66046.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.4	15.0	1.808	1	301.2	2.3	1.234
2	211.4	-21.5	1.319	2	210.9	-10.0	0.939
3	263.9	-14.1	1.213	3	264.0	-17.3	1.196
4	287.5	1.4	1.271	4	286.0	9.7	1.232
5	153.8	5.8	1.224	5	154.4	25.7	1.309
6	165.7	18.7	1.184	6	161.6	56.0	1.202
7	168.5	9.7	1.096	7	169.0	18.9	0.965
8	288.3	0.2	1.378	8	283.6	11.9	1.339

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-11
Current Flight Hours = 77047.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	300.7	21.9	1.668	1	302.2	5.8	1.099
2	212.2	-27.8	1.493	2	212.0	-16.5	0.883
3	263.9	-9.7	1.143	3	263.4	-11.8	1.034
4	287.0	4.0	1.122	4	285.9	10.8	1.151
5	155.1	-24.1	2.369	5	155.8	-7.2	0.951
6	168.2	7.6	2.698	6	162.6	46.5	1.190
7	168.4	1.3	1.644	7	169.5	7.3	0.964
8	286.7	11.6	1.663	8	284.6	17.0	1.163

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-13
Current Flight Hours = 99052.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	299.2	16.1	1.579	1	300.6	1.8	1.301
2	212.2	-22.5	1.324	2	211.8	-9.3	0.939
3	261.6	-15.7	1.259	3	262.7	-21.3	1.207
4	287.3	6.2	1.299	4	286.9	12.5	1.272
5	152.0	2.4	1.113	5	153.3	16.7	1.242
6	165.6	25.8	1.203	6	161.6	62.3	1.122
7	169.4	7.9	1.350	7	170.8	15.9	0.932
8	288.6	7.4	1.368	8	284.7	17.7	1.336

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-14
Current Flight Hours = 109997.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	299.0	18.8	1.373	1	301.0	2.2	1.245
2	212.1	-21.2	1.365	2	212.5	-10.2	0.928
3	261.5	-17.2	1.091	3	261.0	-21.1	1.145
4	288.2	9.2	1.146	4	288.6	15.1	1.195
5	151.4	-3.1	1.189	5	152.9	13.2	1.179
6	166.4	29.0	1.174	6	164.3	55.5	1.521
7	169.9	0.8	1.953	7	172.7	10.1	1.058
8	288.0	9.5	1.182	8	285.7	19.2	1.407

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-14
Current Flight Hours = 109997.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	299.0	18.8	1.373	1	301.0	2.2	1.245
2	212.1	-21.2	1.365	2	212.5	-10.2	0.928
3	261.5	-17.2	1.091	3	261.0	-21.1	1.145
4	288.2	9.2	1.146	4	288.6	15.1	1.195
5	151.4	-3.1	1.189	5	152.9	13.2	1.179
6	166.4	29.0	1.174	6	164.3	55.5	1.521
7	169.9	0.8	1.953	7	172.7	10.1	1.058
8	288.0	9.5	1.182	8	285.7	19.2	1.407

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-15
Current Flight Hours = 121020.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING:				UNLOADING:			
strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	299.0	15.1	1.601	1	299.4	0.0	1.261
2	214.5	-24.4	1.533	2	213.8	-9.3	0.936
3	258.0	-25.1	1.272	3	257.4	-33.9	1.112
4	290.5	10.7	1.421	4	289.4	22.0	1.263
5	150.1	-12.5	1.819	5	151.5	0.4	1.307
6	167.4	26.6	2.150	6	162.2	65.9	1.228
7	172.0	0.1	1.580	7	174.3	7.3	0.915
8	290.4	10.5	1.500	8	286.7	20.7	1.357

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-16
Current Flight Hours = 132075.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	296.7	19.4	1.943	1	298.8	0.0	1.210
2	214.8	-22.3	1.759	2	214.9	-7.5	0.983
3	252.7	-24.5	1.558	3	253.9	-42.9	1.178
4	292.6	13.5	1.366	4	292.5	24.9	1.192
5	147.8	-17.1	2.666	5	147.7	-0.9	1.155
6	170.3	29.1	3.286	6	164.4	70.2	1.333
7	171.6	8.0	2.203	7	176.3	12.3	1.084
8	289.5	17.9	1.785	8	288.5	23.3	1.416

STRAIN LOAD/UNLOAD ANALYZER

File Prefix = cs3-17
Current Flight Hours = 142663.0
Number of Files = 3 with 6 junk lines each
Number of Strain Gages = 8

----------> FILE = averages of all 3 files

LOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV	UNLOADING: strn chan	SLOPE ms/kip	INTER mstrn	STAND DEV
1	291.3	18.8	2.203	1	292.2	-2.2	1.271
2	221.5	-20.9	2.318	2	221.8	-2.0	1.154
3	231.2	-62.9	3.743	3	230.2	-104.8	2.103
4	304.0	37.1	2.456	4	305.1	61.4	1.493
5	126.8	-101.2	1.182	5	126.5	-108.6	1.011
6	170.5	24.0	3.135	6	164.7	64.2	1.327
7	179.4	-12.9	2.075	7	179.0	1.3	0.952
8	296.9	26.3	1.658	8	295.0	33.6	1.304

APPENDIX G3

Crack Growth Analysis Data Files

NASGRO Batch File for Simple Coupon Analysis

```
simple.out   Output file name
         1    1=US units; 2=SI units
d
FCL W1, Test Spectrum (Tension), M6                              (Title)
tc      Crack Model Type
3     Crack Model Number
   1.00000000000000          Width
  0.12500000000000           Thickness
  0.19000000000000           Hole diameter
  0.35000000000000           Hole center to edge
u      U = user defined; S = Standard NDE
  5.000000000000000E-002     Initial a
        C=change; RTN=continue; S=start over
           1    Num of materials
3
2014-T6511 SwRI da/dN data
Mod of McMaster Fit (M6, w/o closure: alpha=5.845, S/So=1.0)
   74.0000000000000          UTS, Matl          1
   65.0000000000000          Yield Str, matl          1
   27.0000000000000          KIE matl          1
   27.0000000000000          K1C, matl          1
   1.00000000000000          Ak - matl          1
   1.00000000000000          Bk - matl          1
w
  2.000000000000000E-009     C
   3.70000000000000          n
  0.50000000000000           p
   1.00000000000000          q
   2.70000000000000          DKo
  0.70000000000000           Rcl
   5.84500000000000          alpha
  1.00000000000000           Smax/SIGo
N     No saving matl file in batch run
        C=change; RTN=continue; S=start over
Single Block Schedule for W1 Coupon Test (Simple)                (Heading)
n Flag for indentifying steps
     100000    No. times to apply sched
          1    No. distinct blocks
n     Yes or No
         73  No. steps - blk          1
          2  Schedule option
TENSION      Block Name
        C=change; RTN=continue
n       Yes or No
          0  Schedule option
        C=change, RTN=continue, S=start over
   1.06000000000000          SF(          1,          1)
  0.000000000000000E+000     SF(          2,          1)
        C=change, RTN=continue, S=start over
n   Ref Load Factor AREF( 1)
          1     SBlk Case
          1     No. of times to apply
          0     SBlk Case
        C=change, RTN=continue, S=start over
        C=change; RTN=continue; S=start over
          1     Print opt. - Sched interval
          1     Print opt. -   Block interval
          0     Print opt. - Indiv step intr
        C=change; RTN=continue; S=start over
          3     Plot option
        C=change; RTN=continue; S=start over
          3     Plot Device No.
          0     Termination option
```

Spectrum File for Simple Coupon Analysis

TENSION W1 Coupon Single Block (550 hr) Equiv. Tension Spectrum

190.0000	-5.0879	-9.4489	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.0000	-4.3610	-10.1758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-3.6833	-10.6119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
957.0000	2.6612	5.3225	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
114.0000	1.7742	6.2096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
57.0000	1.3306	6.6531	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11.0000	0.4435	7.5402	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0000	-0.4435	8.4273	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3306	9.3143	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	1.1089	6.8749	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0000	3.3432	3.3766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44.0000	2.7080	3.5438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22.0000	2.0728	3.7444	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6.0000	1.4180	3.9450	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3810	-9.0855	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.0000	-5.0879	-9.4489	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.0000	-4.3610	-10.1758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-3.6833	-10.6119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1914.0000	2.6635	5.3270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229.0000	1.7757	6.2149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
114.0000	1.3318	6.6588	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23.0000	0.4439	7.5466	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.0000	-0.4439	8.4345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3318	9.3223	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-2.9717	10.9554	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0000	3.3432	3.3766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44.0000	2.7080	3.5438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22.0000	2.0728	3.7444	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6.0000	1.4180	3.9450	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.0000	-5.0879	-9.4489	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.0000	-4.3610	-10.1758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-3.6833	-10.6119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1914.0000	2.6635	5.3270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229.0000	1.7757	6.2149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
114.0000	1.3318	6.6588	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23.0000	0.4439	7.5466	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.0000	-0.4439	8.4345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3318	9.3223	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0000	3.3432	3.3766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44.0000	2.7080	3.5438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22.0000	2.0728	3.7444	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6.0000	1.4180	3.9450	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	1.1089	6.8749	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.0000	-5.0879	-9.4489	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.0000	-4.3610	-10.1758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-3.6833	-10.6119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1914.0000	2.6635	5.3270	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229.0000	1.7757	6.2149	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
114.0000	1.3318	6.6588	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
23.0000	0.4439	7.5466	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
4.0000	-0.4439	8.4345	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3318	9.3223	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-2.9717	10.9554	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0000	3.3432	3.3766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44.0000	2.7080	3.5438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22.0000	2.0728	3.7444	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6.0000	1.4180	3.9450	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
190.0000	-5.0879	-9.4489	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9.0000	-4.3610	-10.1758	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-3.6833	-10.6119	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
3829.0000	2.6612	5.3225	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
457.0000	1.7742	6.2096	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
229.0000	1.3306	6.6531	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
46.0000	0.4435	7.5402	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
8.0000	-0.4435	8.4273	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.0000	-1.3306	9.3143	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-2.2177	10.2014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	1.1089	6.8749	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
28.0000	3.3432	3.3766	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
44.0000	2.7080	3.5438	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
22.0000	2.0728	3.7444	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
6.0000	1.4180	3.9450	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
1.0000	-1.3810	-9.0855	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

0/

NASGRO Batch File for Complex Coupon Analysis

```
CX1t.out            Output file name
          1    1=US units; 2=SI units
d
FCL W1, Complex Test, Spectrum = W1COUP, M6                                    (Title)
tc      Crack Model Type
3     Crack Model Number
   1.43400000000000          Width
  0.125000000000000          Thickness
  0.159000000000000          Hole diameter
  0.375000000000000          Hole center to edge
u      U = user defined; S = Standard NDE
  6.800000000000000E-002    Initial a
        C=change; RTN=continue; S=start over
          1    Num of materials
3
2014-T6511 SwRI da/dN data
Mod of McMaster Fit (M6, w/o closure: alpha=5.845, S/So=1.0)
   74.0000000000000          UTS, Matl           1
   65.0000000000000          Yield Str, matl           1
   27.0000000000000          KIE matl           1
   27.0000000000000          K1C, matl           1
   1.00000000000000          Ak - matl           1
   1.00000000000000          Bk - matl           1
w
  2.000000000000000E-009    C
   3.70000000000000          n
  0.500000000000000          p
   1.00000000000000          q
   2.70000000000000          DKo
  0.700000000000000          Rcl
   5.84500000000000          alpha
  1.000000000000000          Smax/SIGo
N    No saving matl file in batch run
        C=change; RTN=continue; S=start over
Single Block Schedule for W1 Coupon Test (Simple)               (Heading)
n Flag for indentifying steps
      100000   No. times to apply sched
          1   No. distinct blocks
n    Yes or No
         73  No. steps - blk           1
          2  Schedule option
W1COUP        Block Name
        C=change; RTN=continue
n       Yes or No
          0  Schedule option
        C=change, RTN=continue, S=start over
   1.00000000000000          SF(           1,           1)
  1.000000000000000E+000    SF(           2,           1)
        C=change, RTN=continue, S=start over
n   Ref Load Factor AREF( 1)
          1     SBlk Case
          1     No. of times to apply
          0     SBlk Case
        C=change, RTN=continue, S=start over
        C=change; RTN=continue; S=start over
          1     Print opt. - Sched interval
          1     Print opt. -   Block interval
          0     Print opt. - Indiv step intr
        C=change; RTN=continue; S=start over
          3     Plot option
        C=change; RTN=continue; S=start over
          3     Plot Device No.
          0     Termination option
```

Spectrum File for Complex Coupon Analysis

W1COUP Single Block Spectrum (550 hrs) for W1 Coupons

190.00000	-2.1140	-3.9260	-15.6520	-29.0680	0.0000	0.0000	0.0000	0.0000
9.00000	-1.8120	-4.2280	-13.4160	-31.3040	0.0000	0.0000	0.0000	0.0000
1.00000	-1.3892	-4.4092	-12.0744	-32.6456	0.0000	0.0000	0.0000	0.0000
957.00000	1.1040	2.2080	8.1960	16.3920	0.0000	0.0000	0.0000	0.0000
114.00000	0.7360	2.5760	5.4640	19.1240	0.0000	0.0000	0.0000	0.0000
57.00000	0.5520	2.7600	4.0980	20.4900	0.0000	0.0000	0.0000	0.0000
11.00000	0.1840	3.1280	1.3660	23.2220	0.0000	0.0000	0.0000	0.0000
2.00000	-0.1840	3.4960	-1.3660	25.9540	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5520	3.8640	-4.0980	28.6860	0.0000	0.0000	0.0000	0.0000
1.00000	0.4600	2.8520	3.4150	21.1730	0.0000	0.0000	0.0000	0.0000
28.00000	1.3900	1.4039	10.2800	10.3828	0.0000	0.0000	0.0000	0.0000
44.00000	1.1259	1.4734	8.3268	10.8968	0.0000	0.0000	0.0000	0.0000
22.00000	0.8618	1.5568	6.3736	11.5136	0.0000	0.0000	0.0000	0.0000
6.00000	0.5977	1.6402	4.3176	12.1304	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5738	-3.7750	-4.2484	-27.9500	0.0000	0.0000	0.0000	0.0000
190.00000	-2.1140	-3.9260	-15.6520	-29.0680	0.0000	0.0000	0.0000	0.0000
9.00000	-1.8120	-4.2280	-13.4160	-31.3040	0.0000	0.0000	0.0000	0.0000
1.00000	-1.3892	-4.4092	-12.0744	-32.6456	0.0000	0.0000	0.0000	0.0000
1914.00000	1.1040	2.2080	8.2080	16.4160	0.0000	0.0000	0.0000	0.0000
229.00000	0.7360	2.5760	5.4720	19.1520	0.0000	0.0000	0.0000	0.0000
114.00000	0.5520	2.7600	4.1040	20.5200	0.0000	0.0000	0.0000	0.0000
23.00000	0.1840	3.1280	1.3680	23.2560	0.0000	0.0000	0.0000	0.0000
4.00000	-0.1840	3.4960	-1.3680	25.9920	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5520	3.8640	-4.1040	28.7280	0.0000	0.0000	0.0000	0.0000
1.00000	-1.2328	4.5448	-9.1522	33.7402	0.0000	0.0000	0.0000	0.0000
28.00000	1.3900	1.4039	10.2800	10.3828	0.0000	0.0000	0.0000	0.0000
44.00000	1.1259	1.4734	8.3268	10.8968	0.0000	0.0000	0.0000	0.0000
22.00000	0.8618	1.5568	6.3736	11.5136	0.0000	0.0000	0.0000	0.0000
6.00000	0.5977	1.6402	4.3176	12.1304	0.0000	0.0000	0.0000	0.0000
190.00000	-2.1140	-3.9260	-15.6520	-29.0680	0.0000	0.0000	0.0000	0.0000
9.00000	-1.8120	-4.2280	-13.4160	-31.3040	0.0000	0.0000	0.0000	0.0000
1.00000	-1.3892	-4.4092	-12.0744	-32.6456	0.0000	0.0000	0.0000	0.0000
1914.00000	1.1040	2.2080	8.2080	16.4160	0.0000	0.0000	0.0000	0.0000
229.00000	0.7360	2.5760	5.4720	19.1520	0.0000	0.0000	0.0000	0.0000
114.00000	0.5520	2.7600	4.1040	20.5200	0.0000	0.0000	0.0000	0.0000
23.00000	0.1840	3.1280	1.3680	23.2560	0.0000	0.0000	0.0000	0.0000
4.00000	-0.1840	3.4960	-1.3680	25.9920	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5520	3.8640	-4.1040	28.7280	0.0000	0.0000	0.0000	0.0000
28.00000	1.3900	1.4039	10.2800	10.3828	0.0000	0.0000	0.0000	0.0000
44.00000	1.1259	1.4734	8.3268	10.8968	0.0000	0.0000	0.0000	0.0000
22.00000	0.8618	1.5568	6.3736	11.5136	0.0000	0.0000	0.0000	0.0000
6.00000	0.5977	1.6402	4.3176	12.1304	0.0000	0.0000	0.0000	0.0000
1.00000	0.4600	2.8520	3.4150	21.1730	0.0000	0.0000	0.0000	0.0000
190.00000	-2.1140	-3.9260	-15.6520	-29.0680	0.0000	0.0000	0.0000	0.0000
9.00000	-1.8120	-4.2280	-13.4160	-31.3040	0.0000	0.0000	0.0000	0.0000
1.00000	-1.3892	-4.4092	-12.0744	-32.6456	0.0000	0.0000	0.0000	0.0000
1914.00000	1.1040	2.2080	8.2080	16.4160	0.0000	0.0000	0.0000	0.0000
229.00000	0.7360	2.5760	5.4720	19.1520	0.0000	0.0000	0.0000	0.0000
114.00000	0.5520	2.7600	4.1040	20.5200	0.0000	0.0000	0.0000	0.0000
23.00000	0.1840	3.1280	1.3680	23.2560	0.0000	0.0000	0.0000	0.0000
4.00000	-0.1840	3.4960	-1.3680	25.9920	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5520	3.8640	-4.1040	28.7280	0.0000	0.0000	0.0000	0.0000
1.00000	-1.2328	4.5448	-9.1522	33.7402	0.0000	0.0000	0.0000	0.0000
28.00000	1.3900	1.4039	10.2800	10.3828	0.0000	0.0000	0.0000	0.0000
44.00000	1.1259	1.4734	8.3268	10.8968	0.0000	0.0000	0.0000	0.0000
22.00000	0.8618	1.5568	6.3736	11.5136	0.0000	0.0000	0.0000	0.0000
6.00000	0.5977	1.6402	4.3176	12.1304	0.0000	0.0000	0.0000	0.0000
190.00000	-2.1140	-3.9260	-15.6520	-29.0680	0.0000	0.0000	0.0000	0.0000
9.00000	-1.8120	-4.2280	-13.4160	-31.3040	0.0000	0.0000	0.0000	0.0000
1.00000	-1.3892	-4.4092	-12.0744	-32.6456	0.0000	0.0000	0.0000	0.0000
3829.00000	1.1040	2.2080	8.1960	16.3920	0.0000	0.0000	0.0000	0.0000
457.00000	0.7360	2.5760	5.4640	19.1240	0.0000	0.0000	0.0000	0.0000
229.00000	0.5520	2.7600	4.0980	20.4900	0.0000	0.0000	0.0000	0.0000
46.00000	0.1840	3.1280	1.3660	23.2220	0.0000	0.0000	0.0000	0.0000
8.00000	-0.1840	3.4960	-1.3660	25.9540	0.0000	0.0000	0.0000	0.0000
2.00000	-0.5520	3.8640	-4.0980	28.6860	0.0000	0.0000	0.0000	0.0000
1.00000	-0.9200	4.2320	-6.8300	31.4180	0.0000	0.0000	0.0000	0.0000
1.00000	0.4600	2.8520	3.4150	21.1730	0.0000	0.0000	0.0000	0.0000
28.00000	1.3900	1.4039	10.2800	10.3828	0.0000	0.0000	0.0000	0.0000
44.00000	1.1259	1.4734	8.3268	10.8968	0.0000	0.0000	0.0000	0.0000
22.00000	0.8618	1.5568	6.3736	11.5136	0.0000	0.0000	0.0000	0.0000
6.00000	0.5977	1.6402	4.3176	12.1304	0.0000	0.0000	0.0000	0.0000
1.00000	-0.5738	-3.7750	-4.2484	-27.9500	0.0000	0.0000	0.0000	0.0000

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